Proceedings of the American Physical Society

Minutes of the Meeting at the University of California, at Berkeley, California February 3–5, 1949

THE 290th meeting of the American Physical Society was held at the University of California, Berkeley, on February 3–5, 1949. There were at least 200 members of the Society at the meeting, and the attendance at the various sessions varied up to a maximum of about 400. From the point of view of the number of papers presented, this was the largest meeting of the Society ever held on the Pacific Coast. The new University Cafeteria provided excellent service for luncheon and the local arrangements were excellent in every way. The various sessions were presided over by Professors R. T. Birge, R. B. Brode, J. W. Ellis, F. A. Jenkins, and J. Kaplan, of the University of California; Professors C. D. Anderson and W. A. Fowler of the California Institute of Technology, and Professor M. L. Pool of the Ohio State University.

The invited paper by Dr. Frederick Bedell was read by Professor R. T. Birge, because of the absence of Dr. Bedell. In addition to the invited papers which are listed below, it was possible to present all of the papers on the supplementary program, as well as three post-deadline papers. These were "Neutron-Proton Mass Difference from the $D-D$ Reactions" by F. A. Jenkins, A. V. Tollestrup, W. A. Fowler, and C. C. Lauritsen; "Quantization of Magnetic Flux," by L. Onsager of Yale University; and "Comparison of the Flow of Isotopically Pure Liquid He^3 and He^4," by D. W. Osborne, B. Weinstock, and B. M. Abraham of the Argonne National Laboratory.

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

Invited Papers on the General Programme

A New Concept of Catalytic Hydrocarbon Reactions from Isotopic Tracer Studies. Otto Beeck, *Shell Development Company, Emeryville, California.* (40 min.)

Spectroscopic Determination of Molecular Structure. R. Robert Brattain, *Shell Development Company, Emeryville, California.* (30 min.)

Nuclear Reactions Produced by High Energy Neutrons. G. F. Chew and M. L. Goldberger, *Radiation Laboratory, University of California, Berkeley.* (30 min.)

Cloud-Chamber Analysis of the Particles Coming from Carbon when Bombarded by 90-Mev Neutrons. Wilson M. Powell, *Radiation Laboratory, University of California, Berkeley.*

What Led to the Founding of the American Physical Society. Frederick Bedell, *Pasadena, California.* (30 min.)

Recent Experimental Work at the Radiation Laboratory. Robert Thornton, *Radiation Laboratory, University of California, Berkeley.* (30 min.)

Certain Principles Governing Mechanisms of Electrical Discharges Derived from Corona Studies. L. B. Loeb, *University of California, Berkeley.* (30 min.)

Contributed Papers

A1. Rupture Strength of Benzene.* J. J. Donoghue, E. Gerjuoy, and R. E. Vollrath, *University of Southern California.*—Observations have been made by the centrifuge method[1] of the rupture strength of outgassed samples of benzene sealed in Pyrex glass tubes. The equilibrium air pressure ranged from 1 to 10^{-5} cm Hg. In general, highly outgassed samples attained a strength so high that the tube was shattered by the shock of rupture. The maximum strength observed was 82 atmospheres. Increasing the equilibrium air pressure decreased the rupture strength and increased the variability. Very reproducible results have been obtained on some highly outgassed samples. The reproducibility is improved by careful temperature control.

* Work supported by the ONR.
[1] J. J. Donoghue, E. Gerjuoy, and R. E. Vollrath, Phys. Rev. 73, 538(A) (1948).

A2. Relative Electrodynamics. F. W. Warburton, *University of Redlands.*—The reciprocal force equation[1] with the choice of parameter $A=\frac{1}{2}$ describes an apparent transverse mass for an electron moving in a circular path. This value also predicts a magnetic moment of 0.001147 Bohr magneton for a stable tripole electron. As the force on any charge exerted by a moving electron is, on this basis, a function of the latter's velocity, an electrical conductor can be in mechanical equilibrium only when it is not electrostatically neutral. In copper, for example, one atom in three or four should lack an electron. This mechanism of unequal force of a high speed electron and a slower proton on a negative ion, and its prediction of thermal electron emission as well as its suggestions for cosmic-ray emission, are discussed. The propagation equations for the scalar and vector potentials, when developed on the relative basis, are less subjective than the Maxwell equations.

They involve the time derivative of the distance from the emitting dipole to the receiving electron, rather than the classical relative velocity of source and stationary observer. Plane wave solutions in the forms, $\phi_v(t+r/(c-v_r))$ and $\phi_c(t-r/(c+v_r))$, are studied.

[1] F. W. Warburton, Phys. Rev. **69**, 40 (1946).

A3. Quantum-Theory Restrictions on the General Theory of Relativity. M. F. M. OSBORNE, *Naval Research Laboratory, Washington, D. C.*—The limitations set by the uncertainty principle on the measurement of the curvature of space are determined by passing a small test particle around a geodesic triangle. In measuring the curvature of space around a Schwarzchild-solution particle of finite size and physically realized density, it is found that the mass must be at least of the order of 10^4 kilograms, or the curvatures cannot be measured with an accuracy equal to the order of magnitude of the terms in the defining equations $G_{ik}=0$. For smaller masses, the curvatures can only be measured with less accuracy and only over large regions of space. Similar limitations apply to alternative laws of gravitation involving higher derivatives of the metric. It is concluded that in any theory which attempts to unite quantum theory with the general theory of relativity, the relation of the metric to the energy momentum tensor, $G_{ik}-g_{ik}=-KT_{ik}$, must appear only in the large and in a statistical sense, i.e., for large regions of space and large numbers of elementary particles.

A4. A Method for Increasing the Safe Power Input of X-Ray Tubes. A. I. BERMAN, *Stanford University* (Introduced by P. H. Kirkpatrick).—A method for cooling x-ray tubes was devised, based on the moving target principle. The tube itself is gyrated without rotation about its axis, so that a point on the target describes a small circle. Simultaneously, the electron beam is deflected by a rotating magnetic field so that the focal spot rotates in synchronism with, but phased 180° from, the mechanical gyration. The strength of the field is adjusted until the circle which the focal spot traces on the target face equals the target circle. Thus the focal spot remains stationary in laboratory space while rotating on the face of the target. The advantages are (1) it is adaptable to most x-ray tubes with target face perpendicular to the tube axis, and target diameter twice that of the longest dimension of the focal spot, without any modification of tube design; (2) it permits anode cooling without the need for vacuum joints, making it especially useful for continuous operation. Tubes, operating continuously at high power for hours at a time at a gyrating frequency of 6 r.p.s., have been cooled successfully by this method without observable shifting of the focal spot in laboratory space.

A5. Betatron Injection. LEVERETT DAVIS, JR. AND R. V. LANGMUIR, *California Institute of Technology.*—The effect of inhomogeneities in the magnetic field on the radial oscillations of an electron in a betatron is considered by treating motion in a magnetic field that is constant in time but has arbitrary small space variations. The conditions that must be imposed in order that the electron not strike the injecting gun are considered and results bearing on the problem of high energy injection into a betatron, synchrotron, or race track are obtained. It is found that for n approximately $\frac{3}{4}$, a one percent variation in B and in n can change the amplitude of oscillation about the equilibrium orbit by as much as 20 percent, the exact magnitude and sign depending on the phase of the inhomogeneities relative to the position of the gun. There is also usually a tendency for the phase to shift quickly to the point where the amplitude increases and to remain there. Thus, in the absence of other effects injection will be difficult. For properly chosen inhomogeneities, and particularly for inhomogeneities that vary with time, a permanent damping that will assist injection can be produced. Similar but less pronounced effects are obtained for other values of n. This work was assisted by the joint program of the Office of Naval Research and the Atomic Energy Commission.

B3. Measurements of Cosmic-Ray Intensity at High Altitudes.* W. C. ROESCH, A. T. BIEHL, AND H. V. NEHER, *California Institute of Technology.*—During May-June of 1948, Geiger counter telescopes similar to those used previously[1] with balloons were flown in a B-29 airplane at 3.1 meters of water equivalent along approximately the 80°W geographic meridian over the geomagnetic latitude range 0° to 64°N. The following measurements were made: (1) the latitude effect in this range, (2) the east-west effect at a zenith angle of 45° in this range, (3) the north-south effect at high and low latitudes, (4) the zenith angle effect at high and low latitudes (the measurements 1–4 were made with 0, 10, and 20 cm of lead absorber), (5) the total intensity was measured with an electroscope, and (6) the latitude effect of wide showers was investigated. At a pressure of 2.35 meters of water equivalent near the geomagnetic equator an azimuth-zenith experiment was made. One of the chief results of these experiments is that there is approximately the same asymmetries in the hard and soft radiations. This makes it unnecessary to assume different primaries for the two components.

* This work was supported in part by the joint program of the ONR and the AEC.

[1] A. T. Biehl, R. A. Montgomery, H. V. Neher, W. H. Pickering, and W. C. Roesch, Rev. Mod. Phys. **20**, 360 (1948).

B4. Latitude Dependence of Cosmic Rays at 33,000 Feet.* A. T. BIEHL, H. V. NEHER, AND W. C. ROESCH, *California Institute of Technology.*—In a series of eight B-29 flights made from Inyokern, California, during the summer of 1948, continuous recordings of the total vertical cosmic-ray intensity were made as a function of latitude. All measurements were made on the 117° West meridian between the borders of Canada and Mexico, and all but one of the flights were made at an altitude of 33,000 feet. The apparatus consisted of two separate Geiger counter telescopes and associated apparatus as previously used by us[1] with slight modifications. The results of these flights indicate that north of about 51° North magnetic latitude the total vertical intensity of cosmic rays is constant. Data from comparable flights made on different days agreed with each other within the probable error at these northern latitudes. However, south of 51° North a definite decrease of from 5 to 6 percent was found to take place within a few degrees of latitude. South of this break, which occurred at latitudes varying from 51° North to 46° North, the vertical intensity was again constant for at least a few degrees. In two cases evidence was obtained for another step of about the same magnitude at about 41° North. These curves will be presented and discussed.

* This work was supported in part by the joint program of the ONR and the AEC.
[1] A. T. Biehl, R. A. Montgomery, H. V. Neher, W. H. Pickering, and W. C. Roesch, Rev. Mod. Phys. 20, 353 (1948).

B5. Energy of Cosmic-Ray Particles from Ionization Chamber and Counter Telescope Data.* H. V. NEHER, *California Institute of Technology*.—It is well known that the area under the curve of ionization *vs.* depth gives the total energy incident on the top of the atmosphere. Similarly, the area under the curve beyond a given depth, h, gives the energy of all particles at that depth. This ignores energy given to hypothetical particles which never appears in the form of particles that ionize. In a similar way a counter telescope may be used to determine the total energy beyond a given depth provided the average specific ionization is known. Furthermore, the average energy of each ionizing particle may also be determined for any depth. Some of the assumptions and limitations entering into these calculations will be discussed. Application will be made to data taken at the geomagnetic equator and northern latitudes.

* This work was supported in part by the joint program of the ONR and the AEC.

B6. Extensive Penetrating Showers of Cosmic Rays. JOHN ISE, JR., *University of California, Berkeley*.*—Experiments have been carried out at 3020 meters on the density spectrum of extensive cosmic-ray showers, both penetrating and non-penetrating, and on the penetrating power of the extensive penetrating showers. Threefold coincidences were observed between three trays of Geiger counters, of variable but equal area, arranged linearly with a separation of 4.8 meters, with various thicknesses of lead, ranging from 0 to 20 cm, over all counter trays. In all the shielded measurements, the lead thickness at sides and ends of the counter trays was 10 cm. The threefold coincidence rate per hour corrected for accidental coincidences is:

Area of counter trays	0 cm Pb	5 cm Pb	10 cm Pb	15 cm Pb	20 cm Pb
400 cm^2	48.9±0.8	6.14±0.35	0.55±0.08		0.193±0.015
800 cm^2	130 ±5				.588±0 033
1200 cm^2	234 ±3	42.1 ±0.8	4.01±0.28	1.56±0.09	1.18 ±0.064

From these observations the frequency of occurrence of Auger showers with an average particle density of σ can be shown to be proportional to $\sigma^{-2.42\pm0.02}$. For extensive penetrating showers through 20 cm of Pb the corresponding relation is $\sigma^{-2.65\pm0.09}$.

* Assisted by the Joint Program of the ONR and the AEC.

B7. The Range Spectrum of Cosmic-Ray Mesotrons. LAWRENCE S. GERMAIN, *University of California, Berkeley*.—A counter-controlled cloud chamber has been used to investigate the differential range spectrum of mesotrons at sea level. The chamber is 16 inches in diameter, has an illuminated region 5 inches deep, and contains eight lead plates each 8 inches wide and ½ inch thick. A lead absorber of variable thickness, up to 27 inches, may be placed above the chamber. The number of mesotrons observed to stop in the chamber per unit time has been found for various thicknesses of absorber above the chamber. A plot of the counting rate of mesotrons which stop *versus* the thickness of absorber above the chamber reveals a broad low peak which has its maximum at a 6-inch thickness of absorber. The counting rate at the peak is 4.60×10^{-5} count/sec./sterad./g/cm^2 of air. The counting rate with no absorber above the chamber is 4.23×10^{-5} count/sec./sterad./g/cm^2 of air. The peak is not symmetric, falling off more rapidly on the side towards greater thicknesses of absorber. For large thicknesses of absorber, correction must be made for loss of particles due to scattering.

* Assisted by the Joint Program of the ONR and the AEC.

B8. Theoretical Values of Mass and Life-Time of Mesons. J. BARNÓTHY, *Barat College, Lake Forest, Illinois*.—Theoretical considerations* have led to the conclusion that electrons and protons can exist, beside their stable states, in different unstable states of short lifetime. The particles with lifetimes longer than 10^{-10} sec. are:

Mass in m_0		Lifetime in sec.	
212	(205±20 Powell)	$2.17\cdot10^{-6}$	($2.15\cdot10^{-6}$ Rossi)
3028.6		($1.40\cdot10^{-8}$)	
2726.7		($6.07\cdot10^{-8}$)	
2301.8		($6.24\cdot10^{-9}$)	
1396.2		$4.14\cdot10^{-9}$	
1018.2	(990±100 Leprince-Ringuet)	$1.57\cdot10^{-9}$	
718.5		$2.16\cdot10^{-10}$	
495.3		$4.34\cdot10^{-9}$	
335.7	(336±40 Powell)	$2.20\cdot10^{-8}$	($1.1\cdot10^{-8}$ Richardson)
223.8		$2.31\cdot10^{-10}$	
147.9		$3.33\cdot10^{-10}$	
97.0		$2.43\cdot10^{-10}$	
11.0	(11.4 Cowan)	$0.94\cdot10^{-9}$	

Several of these particles have already been observed experimentally as "mesons." A good agreement with the computed values could be stated in all cases where sufficiently exact determinations have been made.

* J. Barnothy, Zeits. f. Physik 120, 148 (1943); Papers of Terr. Magn. Hungary No. 2 (1947).

B9. Compton-Getting Effect of Cosmic Radiation. M. FORRÓ, *Barat College, Lake Forest, Illinois*.—Sidereal time periodicity of the hard component of cosmic radiation was measured over periods of two years with counter telescopes of small aperture, in different zenith angles and with different lead absorbers. The results furnish for the amplitudes of the Compton-Getting effect values up to one-half percent. The maximum is shifted toward later hours when the thickness of the absorber is increased. (The shift is 8 hours for every 20 cm Pb.) A linear connection can be stated between logarithm of the minimal energy of the radiation and the phase shift of the maximum. With the help of certain assumptions, it was possible to compute from this connection the time of rotation of the Milky Way to 234±10 million years, in agreement with the astronomically determined value.

C1. 10-Mev Magnetic Proton Spectrograph. SYLVAN RUBIN,* *California Institute of Technology.*—A large magnetic spectrograph of the double-focusing type[1] is now under construction. Heavy charged particles will be deflected on a 180° path of 16-in. mean radius in a field decreasing as $r^{-\frac{1}{2}}$. The gap is 2 in. between pole faces and 6 in. wide, containing a brass vacuum chamber, shaped to the contour of the pole faces. It will be connected to the target chamber and particle detector, both located outside the field. The solid angle for detection will be ~ 0.01 steradian. For maximum magnetic efficiency, the coils will be wound around the C-shaped poles, using $\frac{3}{8}'' \times \frac{3}{32}''$ Formvar coated copper strip in 16 layers, water-cooled by 8 interleaved layers of copper tubing. 50,000 ampere turns will be obtained at 120 volts, dissipating 15 kw in the coils, giving a field of 10–11 kilogauss in the gap. The return flux path will be divided between the center and the rim, a 48-in. dia. semicircle. The magnetic field will be measured and calibrated by the same technique used on the present 2-Mev spectrograph[2] with the additional possibility of calibrating with natural alpha-groups.

* Now with Stanford Research Institute.
[1] Svartholm and Siegbahn, Arkiv f. Astro., Math., Fys. **33A**, No. 21 (1946).
[2] Snyder, Lauritsen, Fowler, and Rubin, Phys. Rev. **74**, 1564A (1948).

C2. Automatic Slit-Width Adjuster for an Infra-Red Spectrometer. H. O. MCMAHON, GILBERT W. KING, AND R. M. HAINER, *Arthur D. Little, Inc., Cambridge, Massachusetts.*—A mechanism adjusting slit widths to give the same energy on the detector at all wave numbers allows the actual record to be percent absorption directly in a single-beam instrument. Even if this is accomplished by double beams, or alternating the beam between sample and blank, this slit drive allows constant signal to noise and hence maximum resolution at all wave numbers. The slit width as a function of wave number depends on many variables, such as source temperature, detector sensitivity, which may be changed from time to time. Thus the basic element is a template which can be easily drawn, shaped, and replaced. This template is mounted on a carriage moved on rails by a punched steel tape driven directly from the shaft which rotates the Littrow mirror. The template, a $\frac{1}{8}''$ steel plate cut to shape, drives a rod vertically, whose motion is communicated by a steel tape through a pulley arrangement to the shaft which opens the slit jaws.

For NaCl a range of 18 to 1 in slit width can be achieved, to cover the range 3000 to 700 cm^{-1}. The template can be cut without difficulty to give no irregularities causing spurious noise, and to give a 100 percent curve flat within variations caused by source temperature and drift.

C3. Radiation Accompanying Meson Creation. L. I. SCHIFF, *Stanford University.*—The electromagnetic radiation that is produced during the creation of charged vector mesons in nucleon-nucleon encounters is investigated in order to determine if it can contribute appreciably to the soft component of cosmic radiation. Since there is, at present, no reliable theory of meson creation, the calculation is performed in analogy with the first method used by Knipp and Uhlenbeck[1] for treating the radiation accompanying beta-decay. Radiative transitions from a point-source or extended-source meson state to plane waves are computed with the help of Gunn's formalism.[2] Preliminary results indicate that the probability for emission of hard quanta by relativistic vector mesons is proportional to the product of the fine-structure constant and a power of the ratio of primary meson energy to rest energy; this is in contrast to the electron case, in which the power is replaced by a logarithm. Such radiation may therefore be of significance in cosmic radiation.

[1] J. K. Knipp and G. E. Uhlenbeck, Physica **3**, 425 (1936).
[2] J. C. Gunn, Proc. Roy. Soc. **A193**, 559 (1948).

C4. Decay Time of π-Meson. R. LATTER AND R. F. CHRISTY, *Kellogg Radiation Laboratory, California Institute of Technology.*—The lifetime for $\pi-\mu$-decay was computed assuming the Bethe-Marshak two-meson hypothesis (wherein π and μ are directly coupled) and taking the π a scalar, vector, or pseudoscalar from nuclear force theory, the μ a scalar, pseudoscalar, or spin $\frac{1}{2}$, from burst evidence, and the secondary neutral meson of the same character as the μ. Using all permissible combinations of these fields, using $\mu=212m$, $E_\mu=3.8$ Mev in the $\pi-\mu$-decay, and τ_μ for nuclear capture $\sim 3.3\times 10^{-6}$ sec. for $Z=10$, the lifetimes found for a range of m_π from $274m$ to $350m$ are $\tau(\text{pseudosc.}\rightarrow\text{spin}\frac{1}{2})\sim 0.3-2.1\times 10^{-9}$ sec., $\tau(\text{vector}\rightarrow\text{scalar or pseudosc.})\sim 1.1-1.4\times 10^{-6}$ sec., $\tau(\text{scalar}\rightarrow\text{scalar or pseudosc.})\sim 1.5-1.9\times 10^{-8}$ sec., $\tau(\text{vector}\rightarrow\text{spin}\frac{1}{2})\sim 0.3-4.0\times 10^{-8}$ sec., and $\tau(\text{scalar}\rightarrow\text{spin}\frac{1}{2})\sim 0.9-1.6\times 10^{-8}$ sec. These numbers may be too high by a factor of 10 or too low by a factor of 3 because of the uncertainty in $g^2/\hbar c$ and by taking the nuclear matrix elements equal to Z. Instead of the Bethe-Marshak hypothesis it is possible to assume that the π and μ are coupled directly to nucleons but not to each other. Divergences in the $\pi-\mu$ decay calculation have prevented quantitative evaluation of this formulation. This work was assisted by the joint program of the Office of Naval Research and the Atomic Energy Commission.

C5. The Spins of the Mesons.* R. SERBER, *University of California, Berkeley.*—The meson mass measurements which show that the third particle involved in $\pi-\mu$ decay has zero mass lead us to seek a description of the phenomena without introducing any new particles. The spins of the mesons are then determined by the capture processes of μ^-- and π^--mesons: (1) $P+\mu^-\rightarrow N+\nu$ (ν=neutrino), (2) $P+\pi^-\rightarrow N$. The lack of stars in μ^- capture shows that a particle is emitted which carries off the energy. Since neither electrons nor γ-rays are emitted, this particle must be a neutrino. Since π^--capture does produce stars, an additional particle cannot be involved in (2). It follows that the μ has spin $\frac{1}{2}$, while the π has spin 0 or 1. The $\pi-\mu$-decay must be (3) $\pi\rightarrow\mu+\nu$. These reactions are not independent; (1) is a consequence of (2) and (3). The μ-decay takes the form (4) $\mu\rightarrow e+2\nu$, and one expects a continuous electron spectrum. Calculation shows that this spectrum is considerably concentrated towards the upper limit, which helps explain the conflicting experiments on this subject.

* The work described was sponsored by the AEC.

C6. A Theorem on Cross Sections. G. C. WICK, *University of California, Berkeley.*—An elementary generalization is given of a known theorem connecting the total cross section σ with the imaginary part of the elastically scattered amplitude in the forward direction $ImF(0)$. The derivation holds for the collision between two particles with arbitrary spin interactions. $ImF(0)$ is written as a matrix $B(m,m')$ where $m=(m_1m_2)$ and $m'=(m_1'm_2')$ represent the spin quantum numbers of the colliding particles before and after the collision. The theorem states that: $\sigma=2\lambda\Sigma_m B(m_1m)/W$, where $W=\Sigma_m 1=(2I_1+1)(2I_2+1)$. It follows that the elastic cross section per unit solid angle in the forward direction is $\geq(\sigma/2\lambda)^2$, λ being the (relative) wave-length. A more detailed discussion of special cases will be presented.

C7. Thermodynamic Theory of the Magnetic Transition Curve of Superconductors. OTTO HALPERN, *University of Southern California, Los Angeles, California.*—The problem of the transition curve[1,2] of superconductors in a magnetic field is re-examined. The point of special interest is the small (or vanishing) heat of reaction for zero magnetic field. The difficulties[3] arising from this fact for the thermodynamic interpretation are discussed; it is proposed that the critical field H_c just below the field free transition temperature T_0 be given by the expression:

$$H_c=A(T_0-T)^{1\frac{1}{3}}+B(T_0-T)^{\frac{3}{2}}+\cdots.$$

Here A and B are constants determined by the heat of reaction and the discontinuity in the specific heats at T_0. Our relation is compared with Rutgers[1] formula, and experiment. The discussion is extended to very low temperatures.

[1] A. J. Rutgers, Physica **1**, 1055 (1934).
[2] Gorter and Casimir, Physica **1**, 306 (1939); Physik. Zeits. **35**, 963 (1934).
[3] P. S. Epstein, *Textbook on Thermodynamics* (New York, 1937), pp. 357–359.

C8. Determination of the Rate of Biochemical Reactions.* C. A. TOBIAS, *University of California, Berkeley.*—The turnover of a number of elements in the plant or animal body may be regarded as a series of steady-state reactions. The time distribution of radioactive tracers introduced to the body, however, does not represent a steady state. If certain initial conditions are fulfilled when the tracer is administered, a set of first-order linear differential equations with constant coefficients may be written, describing the turnover of the tracer in the body, assuming n different states, exchange between each pair of states as well as between the states and an external reservoir. The solution may be obtained in terms of a sum of a set of n exponentially varying functions of time, the decay constants being the "eigenvalues" of the problem. In experiment one may actually observe the time dependence of the concentration of the radioactive tracer in each state. By analyzing such data into a sum of n exponential functions, one obtains the eigenvalues, and one may also calculate the turnover rate of the carrier element between all states. The method will be illustrated by examples from human iron metabolism, where such calculations led to the identification of a new intermediary.

* This work was carried out under the auspices of the AEC.

D3. Corona Studies in Nitrogen, Oxygen, and Mixtures.* CHARLES G. MILLER,** *University of California, Berkeley.*—D.c. corona studies have been carried out in concentric cylindrical systems covering the pressure range 715 mm to 27 mm in pure nitrogen, pure oxygen, and in mixtures. Self-sustaining corona discharges in pure nitrogen depend exclusively on γ at the cathode. In positive wire corona this leads to a discharge visible as *anode spots;* in negative wire corona this leads to disruptive currents if the nitrogen is quite pure. Self-sustaining positive corona in pure oxygen gives streamers at high pressures, burst pulses at low pressures, indicating high photon absorption and high photo-ionization in the gas; self-sustaining high current negative corona in oxygen depends on Trichel pulses. It is shown that the Trichel pulse onsets in oxygen and mixtures are not real thresholds set by a second Townsend coefficient. These negative thresholds depend on a preliminary Townsend discharge cleaning up the cathode, giving way to Trichel pulses as a second mode. It is shown that Trichel pulses in oxygen depend on O_2^-, while Trichel pulses in mixtures depend also on negative ions of nitrogen oxides. Comparison of the onset potentials, positive and negative, at various percentages of oxygen are made at various pressures, and throw some light on the relative importance of factors affecting corona thresholds.

* This work was supported in part by the Research Corporation.
** Now at the University of California, Santa Barbara College.

D4. Dust Electrostatics.* WULF KUNKEL, *University of California, Berkeley.*—Previous results with the Hopper-Laby method of analysis of blow electrified dusts indicated these to be groups of large aggregates of the ultimate grains. The unsatisfactory correlation of these aggregates with grain size observed by microscope on collector slides in the chamber led to instrumental refinements in observation of the smaller grains and elimination of minute convection currents. The smallest microscopically observed grains can now reliably be observed. In consequence it appears, as observed by rate of fall, that while the main *bulk by volume* of blown dusts always consists of larger aggregates, these are invariably and distinctly *outnumbered* by the ultimate grains in agreement with microscopic studies of the settled dusts gathered on microscope slides in the chamber. Earlier rate of fall results had been falsified by small upward and downward convection currents which had either eliminated small particles or made them appear larger by increased fall rates. Present data show the small particles to carry relatively smaller charges than previously found on the larger aggregates. The latter have not been restudied since refinement. No sign preference has been detected to date using homogeneous dusts on surfaces of the same material.

* This work is being carried on under an ONR contract.

D5. Purification and Comparison of Some Organic Phosphors for Scintillation Counters.* JOHN W. IRVINE, JR. AND RAYMOND C. SANGSTER, *Massachusetts Institute of Technology.*—Naphthalene, anthracene, phenanthrene, and other aromatic hydrocarbons are purified by passing their hexane or benzene solutions through a heated column of activated alumina. Using an RCA 1P28 at room temperature as a detector and Co^{60} gamma-rays for excitation, the different phosphors are compared under identical conditions. With the test arrangement used a plot of log counting rate *vs.* discriminator voltage gives a straight line over a 40-volt range. This curve can be described by specifying the ordinate intercept (I) and slope (voltage to reduce counting rate to one-half).

	$I\times10^{-4}$	$V_{\frac{1}{2}}$
Naphthalene (Bakers C.P.)	2.2	1.7
Naphthalene (Al_2O_3 purified)	3.4	2.1
Anthracene (melted in air)	1.0	4.0
Anthracene (melted in N_2)	1.0	6.0
Phenanthrene (Al_2O_3 purified)	1.7	3.0
Stilbene (EKC)	1.9	3.3
1 percent anthracene in naphthalene	3.3	5.3
1 percent phenanthrene in naphthalene	4.5	2.1

The purity of a phosphor has a marked effect on its performance.

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

D6. Life Tests on Self-Quenching Geiger-Mueller Tubes with Halogen and Polyatomic Gases as Quenching Agents. F. W. Brown III, P. J. Harris, and A. L. Klein, *Naval Radiological Defense Laboratory.*—Several tubes have been filled with argon as a counting gas, and ethyl alcohol, ethylene,[1] amyl acetate, or 1-butene as the quenching gas. These tubes were counted at a rate of about 3000 counts/second and the plateaus were measured at selected intervals. The lifetimes were 2.2×10^9 for ethyl alcohol, 3×10^9 for ethylene, 1.3×10^{10} for amyl acetate, and 1.4×10^{10} total count for 1-butene. Mass spectrographic analyses have been completed giving the breakdown products of the quenching gases. Tubes have been filled with a mixture of neon and argon as the counting gas, and chlorine[2] as the quenching agent. These tubes have been counted at a rate of 6000 counts/second and are giving good results after having counted 3.5×10^{10} counts. Indications are that their lifetime is limited only by absorption or by chemical removal of the chlorine.

[1] K. H. Morganstern, C. L. Cowan, and A. L. Hughes, Phys. Rev. **74**, 499 (1948).
[2] S. H. Liebson and H. Friedman, Rev. Sci. Inst. **19**, 303 (1948).

D7. Effects of Temperature on Naphthalene and Anthracene Scintillation Counters. G. E. Koch and J. D. Graves, *Naval Radiological Defense Laboratory.*—The temperature dependence of the particulate gamma-counting efficiency of naphthalene and anthracene scintillation counters has been investigated in the regions between −80°C and +50°C. All pulses occurring above a fixed level determined by the noise level of the 931A photo-multipliers at the maximum temperature encountered (+50°C) were counted directly by a commercial scaler. The time required for a fixed number of counts was observed to be about twofold for naphthalene and fourfold for anthracene. The temperature and counting rate for the end point, and the maxima and minima of the curve for naphthalene and anthracene are shown in the table using arbitrary counting rate scales of 10.

Temperature	Counting rate in naphthalene	Counting rate in anthracene
−80°C	8	4.5
−30°C	4.5 (minimum)	—
+10°C	10 (maximum)	10 (maximum)
+50°C	8.5	2.5

D8. A Laboratory Alpha-Scintillation Counter. J. D. Graves and J. P. Dyson, *Naval Radiological Defense Laboratory.*—A reliable, wide-range alpha-scintillation counter has been developed for use with small samples. It utilizes the 931A photo-multiplier, a commercial ZnS phosphor, and a commercial scaler and power supply. For 4–5 Mev α from a sample up to $\frac{1}{4}$ inch in diameter, 100 percent efficiency is observed with 40 percent geometry. This efficiency remains constant over a wide range of phosphor thickness and temperature. With discrimination at the photo-multiplier noise level, a background count of about 10 counts per hour is observed. The resolving time is less than 1 microsecond. For continuous counting, however, the upper counting rate is limited by fatigue of the tube rather than the resolving time. A light lock is required for sample changing caused by the phosphorescence resulting from the exposure of the phosphor to daylight. The counter is insensitive to changes in humidity and pressure, and tube voltage over a wide range, and is free from microphonic effects.

D9. Optical Method for Improving the Counting Efficiency of Scintillation Counters. R. H. Davis and J. D. Graves, *Naval Radiological Defense Laboratory.*—Optical methods of increasing the counting efficiency of scintillation counters by increasing the field of view have been studied. With extended phosphors, the photo-cathode only normally "sees" a small fraction of the scintillations. For truncated Lucite cones, it was found that the detection efficiency increased as the angle of the cone was made smaller. Consequently, various diameters and lengths of cylindrical glass tubing, provided with a reflecting coating, were tested using an extended 5-Mev$\alpha ZnS:Ag$ scintillation source. It was found that the maximum counting rate when using the glass tubes was about 20 percent greater than that when using the direct field of view. The dimensions of the glass tube for maximum counting rate occurred when the length was $\frac{1}{2}''$ long and $2''$ diameter for a 931A tube. For the direct field of view the greatest counting rate occurred when the position of the phosphor screen was as close as possible to the 931A photo-multiplier. In this position the tube could see a circular area about $\frac{3}{4}''$ in diameter. Consequently, this system gives about a sevenfold increase in area of detection as well as a 20 percent increase in counting efficiency.

D10. The Chi Square Test as a Criterion for Testing Halogen-Filled Geiger Tubes. A. B. Willoughby, *Naval Radiological Defense Laboratory* (Introduced by Richard I. Condit).—In the past the maximum acceptable plateau slope for organic quenched Geiger tubes has been about five percent. The newly developed halogen quenched tubes have an inherent slope of about six percent or more. Since the latter tubes appear to have an infinite life, it was decided to re-examine the criterion for acceptance of tubes. As a basis for a new criterion, the fact will be used that a good Geiger tube yields an output of counts per unit time that has a Poisson distribution. It is proposed that all tubes be statistically tested using the Chi Square Test to ascertain whether they give this Poisson distribution. If they do, they are accepted. In applying this test at various points along the plateau slope of a number of halogen-quenched tubes, it was found that the tubes passed the test for quite high values of ρ (at least $\rho=1.5$) where ρ is defined as the ratio of the counting rate at any voltage E to the counting rate at threshold. A Geiger tube which passes the Chi Square Test at the highest operating voltage was found always to pass it at any lower voltage. Thus the proposed criterion for accepting a halogen-quenched Geiger tube reduces to whether or not it passes the Chi Square Test at its highest operating voltage.

E1. Converter Thickness Corrections in Gamma-Ray Spectroscopy.* T. LAURITSEN AND W. F. HORNYAK, *Kellogg Radiation Laboratory, California Institute of Technology.*—The effect of converter thickness on the location of the photo-electron peak for γ-radiation converted in thorium foils has been studied, using a lens-type spectrometer. Spectrometer resolutions of 1.5 percent and 3.0 percent were used, with foils ranging in thickness from 7 to 150 mg/cm^2, and γ-rays ranging in energy from 0.4 to 3.1 Mev. For γ-ray standards the 2.620-Mev radiation from ThD, the 411.1-kev radiation from Au^{198}, and the annihilation radiation from N^{13} were used. The γ-radiations from Co^{60} and the reactions $Be^9(d,n)B^{10*}$ and $C^{12}(d,p)C^{13*}$ were used as auxiliary sources. The F, I, and X internally converted lines from atomic layer deposits of ThB were used as mono-energetic electron sources. For the higher instrument resolution, the high energy extrapolated edge was found to be largely independent of converter thickness at all γ-ray energies. At low energies and for saturation thicknesses, the shift in the location of the photo-line peak is proportional to the absolute resolution, while at high energies and thicknesses small compared to the saturation thickness, the shift is just the most probable collision energy loss in half the converter thickness. A semiempirical expression has been developed to give the shift as a function of γ-ray energy, resolution, and converter thickness.

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

E2. The Beta-Decay Spectra of B^{12} and Li^8.* W. F. HORNYAK AND T. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The β-spectrum of Li^8 has been calculated from the Fermi theory of β-decay using as the density of states available in Be^8, the α-particle spectrum resulting from its subsequent break up.[1] A comparison of this predicted spectrum with the experimental one obtained at this laboratory[2] indicates close agreement above an electron kinetic energy of 6.0 Mev and gives a Li^8-2He^4 mass difference of 15.9 ± 0.1 Mev. The deviation of the observed spectrum from the predicted spectrum below 6.0 Mev can be taken to indicate that about 10 percent of the disintegrations go to narrow states in Be^8, at 9.7 ± 0.3 and $\sim$13 Mev, which do not decay by α-particle emission. It is estimated that less than 2 percent of the β-decay is to the ground state of Be^8 and less than 5 percent to the gamma-ray emitting state at 4.8 Mev, the majority of transitions being accounted for by a broad state at $\sim$3 Mev. The Kurie plot of the B^{12} β-spectrum[2] is linear from an electron kinetic energy of 6.0 Mev to the end point. The end point of 13.43 ± 0.06 Mev when combined with the mass of C^{12}[3] gives 12.01827 ± 0.00009 a.m.u. for the mass of B^{12}. If 5 percent of the β-decay is assumed to go to a narrow level in C^{12} at 7.1 ± 0.5 Mev and possibly a broad or composite level at $\sim$11. Mev, the observed non-linearity of the Kurie plot below 6 Mev can be accounted for. A decay of 5 percent or less to the 4.3-Mev level in C^{12} cannot be excluded.

* This work was assisted by the joint program of the ONR and the AEC.
[1] Bonner, Evans, Malich, and Risser, Phys. Rev. **73**, 885 (1948).
[2] W. F. Hornyak and T. Lauritsen, Phys. Rev., to be published.
[3] E. R. Cohen and W. F. Hornyak, Phys. Rev. **72**, 1127 (1947).

E3. Gamma-Radiation and Nuclear Pairs from $F^{19}+p$.* V. K. RASMUSSEN, W. F. HORNYAK, AND T. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The reaction $F^{19}(p,\alpha)O^{16*}$ leaves O^{16} in an excited state at about 6 Mev[1] which can decay only by the emission of positron-electron pairs, as well as in two other states yielding gamma-rays of 6.1 and 7.0 Mev, respectively.[2] The radiation from these three states has been studied in some detail, using a magnetic lens spectrometer to measure the energy spectra of the nuclear pairs and of the secondary electrons from the γ-rays. The pair spectrum is found to extend to an upper energy limit of 5.04 ± 0.04 Mev, and the distribution of both positive and negative particles corresponds closely with theoretical expectations above $\sim$2 Mev.** Compton electrons from the γ-rays were examined at bombarding energies of 873, 939, 1352, and 1379 kev corresponding to known resonances, using thin CaF_2 targets and Be converters. A fit to the observed data by shapes calculated from the Klein Nishima formula taking into account the effects of spectrometer geometry and of energy loss in the converter yielded mean values of 6.16 ± 0.04 and 7.06 ± 0.06 for the γ-ray energies, in good agreement with the values 6.13 ± 0.06 and 6.98 ± 0.07 given by Walker and McDaniel.[2] The observed intensity ratios (6 Mev/7 Mev) are 2.5, 3.3, 1, and 4.7, respectively, at the four resonances.

* This work was assisted by the joint program of the ONR and the AEC.
[1] W. F. Hornyak and T. Lauritsen, Rev. Mod. Phys. **20**, 191 (1948).
[2] R. L. Walker and B. D. McDaniel, Phys. Rev. **74**, 315 (1948).
** We are indebted to Mr. E. R. Cohen for these calculations.

E4. Cross Sections for $C^{12}(p\gamma)$ and $N^{14}(p\gamma)$ Reactions at low Energy.* E. J. WOODBURY, R. N. HALL,** AND W. A. FOWLER, *Kellogg Radiation Laboratory, California Institute of Technology.*—Cross-section measurements for the reaction $C^{12}(p\gamma,\beta^+)C^{13}$ previously reported[1] have been confirmed. Four thick graphite yield determinations at 128-kev bombarding energy gave 7.1 ± 0.6, 7.3 ± 2.7, 8.0 ± 2.4, and 9.2 ± 0.7 positrons per minute per one-hundred microcoulombs with a counting efficiency of 26 percent. The cross section is calculated to be $8.5\pm1\times10^{-10}$ barn. The cross section decreases rapidly with decreasing bombarding energy in a manner consistent with barrier penetration factors and is equal to 10^{-10} barn at 95 kev. A sufficient number of positrons have been counted to give a rough determination of the half-life as 8 ± 2 minutes. The reaction $N^{14}(p\gamma,\beta^+)N^{15}$ has also been studied at 128 kev using a thick target of titanium nitride which showed no appreciable deterioration under extensive bombardment. The cross section was found to be $\sim7\times10^{-10}$ barn but this must be considered to be a lower limit because of the possibility of the escape of O^{15} from the target. These measurements indicate that at stellar temperatures the nitrogen reaction rate is approximately 1/35 that of the carbon reaction rate giving an abundance ratio $N^{14}:C^{12} \sim 35:1$. As this differs from the roughly equal abundances observed for nitrogen and carbon by Aller and Unsöld in hot stars, the problem of the O^{15} escape must be investigated more throughly. However, preliminary yield measurements under somewhat more satisfactory conditions at the first observable nitrogen resonance (277 kev) indicate a radiation width of about 0.01 ev which is only 2 percent of that at the first carbon resonance.

* This work was assisted by the joint program of the ONR and the AEC.
** Now at the General Electric Company, Schenectady, New York.
[1] W. A. Fowler and R. N. Hall, Phys. Rev. **74**, 1558A (1948).

E5. The Scattering of Protons by Lithium.* W. A. Fowler, C. C. Lauritsen, and S. Rubin,** *Kellogg Radiation Laboratory, California Institute of Technology.*—The cross section for the elastic scattering of protons by Li^7 has been measured over the range of bombarding energies from 250 to 1350 kev at angles of 81.1° and 137.8° in laboratory coordinates. Thick layers of natural lithium deposited in vacuum have been employed as targets. A double-focussing magnetic spectrometer was employed to analyze the energy of the scattered particles. In this way it was possible to measure the number of protons scattered from thin layers (~3-kev stopping power) of the target and to separate those scattered by Li^7 from those scattered by Li^6. At both scattering angles the observed cross section agrees approximately with Rutherford scattering except at 440 kev and 1020 kev. The anomaly at 440 kev is associated with the narrow resonance in the $Li^7(p\gamma)$ reaction. The maximum ratios to Rutherford scattering are 2.36 at 137.8° and 1.60 at 81.1°. The anomaly at 1020 kev is associated with a broad resonance in the inelastic scattering of protons by Li^7. The maximum elastic scattering cross sections are 1.41 barns at 81.1° and 1.22 barns at 137.8° while the maximum in the inelastic scattering as measured both by the number of protons and the intensity of the subsequent gamma radiation is 0.07 barn.

* This work was assisted by the joint program of the ONR and the AEC.
** Now at the Stanford Research Institute, Los Angeles, California.

E6. The Disintegration Energy of Be^8.* A. V. Tollestrup, C. C. Lauritsen, and W. A. Fowler, *Kellogg Radiation Laboratory, California Institute of Technology.*—Bombardment of Be^9 by protons leads to the reactions (1) $Be^9(p,d)Be^8$ and (2) $Be^9(p,\alpha)Li^6$. The residual Be^8 is unstable to disintegration into two α-particles. The recoil of the Be^8 nucleus leads to a continuous energy distribution of the resulting α-particles. The Q of the deuteron reaction and the end point of the Be^8 α-spectrum can be measured and thereby the amount of energy by which Be^8 is unstable can be calculated. A double focusing magnetic spectrometer has been used to separate the particles of the above two reactions and to measure accurately their energies. The particles were detected with a scintillation counter essentially of the type described in the references below.[1,2] The residual nucleus Li^6 in the doubly ionized state slightly overlaps in momentum the doubly ionized Be^8 decay alphas, because of energy loss in the beryllium foil. Therefore, it was necessary to supplement magnetic analysis by the use of stopping foils. This was also necessary in the second reaction since the doubly charged Li^6 ions and the accompanying doubly charged α-particles have nearly the same momentum. The results of the analysis are: $Q_1 = 555 \pm 3$ kev, $Q_2 = 2117 \pm 11$ kev, and Be^8 is unstable by 84.5 ± 10 kev.

* This work was assisted by the joint program of the ONR and the AEC.
[1] Marshall, Coltman, and Bennett, Rev. Sci. Inst. **19**, 744 (1948).
[2] A. V. Tollestrup, Phys. Rev. **74**, 1561 (1948).

E7. Beryllium-Proton Reactions and Scattering.* R. G. Thomas, W. A. Fowler, and C. C. Lauritsen, *Kellogg Radiation Laboratory, California Institute of Technology.*—The cross sections of the reactions $Be^9(p,d)Be^8$, $Be^9(p,\alpha)Li^6$, and $Be^9(p,p)Be^9$ have been remeasured[1] at 138° in the range of bombarding energies from 250 to 1300 kev using a high resolution double-focusing magnetic spectrograph[2] for reaction particle analysis. Detection was by means of an ionization chamber, and pulse size discrimination was necessary to discriminate deuterons and alpha-particles at low energies where their curvature in the magnetic field is the same. The proton scattering cross section shows prominent anomalies at 330, 988, and 1077 kev corresponding to $Be^9(p,\gamma)B^{10}$ resonances.[3-5] Over the 988-kev resonance the ratio to Rutherford scattering varies from 0.8 at 920 to 5.1 at 1030 kev. The alpha-particle reaction shows resonance or interference effects at 330 and 988 kev. The deuteron reaction shows resonance or interference effects at 330, 440, and 988 kev. The maximum cross sections for these reactions are 0.3 and 0.4 barn, respectively at 330 kev.

* This work was assisted by the joint program of the ONR and the AEC.
[1] R. G. Thomas, W. A. Fowler, and C. C. Lauritsen, Phys. Rev. **73**, 536 (1948).
[2] Snyder, Lauritsen, Fowler, and Rubin, Phys. Rev. **74**, 1564 (1948).
[3] C. C. Lauritsen, T. Lauritsen, and W. A. Fowler, Phys. Rev. **72**, 739 (1947).
[4] Curran, Dee, and Petrzilka, Proc. Roy. Soc. **169**, 269 (1939).
[5] Hole, Holtsmark, and Tangen, Naturwiss. **28**, 335 (1940).

E8. Proton Scattering by Li^7 and Be^9.* E. Richard Cohen, *California Institute of Technology.*—Proton scattering resonances reported in an accompanying abstract by Lauritsen *et al.*, have been analyzed for the purpose of determining the angular momentum of the compound nucleus and the relative orbital momentum of the protons.

In the reaction $Be^9(p,p)Be^9$ there is a broad resonance at 988 kev which we ascribe to incident s-wave protons forming a compound B^{10} nucleus with $J=2$. With the usual assignment of odd parity to Be^9 and even parity to the ground state of B^{10}, the observed γ-ray is electric dipole (spin of $B^{10}=3$). For an adequate description it has been necessary to include a nuclear potential scattering for the s-waves. Other choices, considering incident s-wave and $J=1$ or incident p-wave and $J=0, \cdots, 3$ have been tried and excluded. The narrow resonance at 1084 kev has been ascribed to incident p-wave and $J=0$.

In Li^7 the well-known 440-kev resonance has been ascribed to incident p-wave forming a compound Be^8 with $J=1$. The resonance at 1020 kev is not inconsistent with an assignment to incident s-waves forming a compound nucleus with $J=1$ but the presence of a broad resonance at higher bombarding energies precludes a detailed agreement.

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

E9. Angular Distribution of γ-Rays from Lithium.* R. F. CHRISTY, *Kellogg Radiation Laboratory, California Institute of Technology*.—Recent work in this laboratory analyzed by E. R. Cohen[1] suggests that the 440-kev resonance in Li is due to p-wave protons. This, combined with the recent discovery of Devons and Hine[2] that the resonant and non-resonant γ-rays are of different parity requires the non-resonant γ-rays to be due to s-wave protons. Indeed, the intensity of non-resonant γ's is much too great to suppose they are in competition with the p-wave α-reaction. However, the resonant γ-ray going to $J=0$ in Be^8 will then be distributed as $1+0.7\cos^2\theta$. The apparent symmetry of the resonant γ's is then only understandable if the mixture of 17- and 14-Mev γ's results in approximate symmetry which requires that the ground state of Be^8 have $J=2$ and that the 17-Mev γ be an appropriate mixture of electric quadrupole and magnetic dipole. The ratio of 17- to 14-Mev radiation which is 2:1 forward would then be 4:1 at 90°.

* This work was assisted by the joint program of the ONR and the AEC.
[1] See accompanying abstract.
[2] S. Devons and M. G. N. Hine, Phys. Rev. 74, 976 (1948).

E10. Relative Magnetic Moments of H^1 and H^2. E. C. LEVINTHAL, *Stanford University, Stanford, California*.*—A careful re-examination of the relative moments of proton and deuteron has been made. The results lie within the error first reported.[1] While the essence of the method has been unchanged, the technique of observing has been considerably improved. The different line shapes of the proton and deuteron signals has been understood in terms of the relaxation time and spin. Because of these different line shapes it was important that the symmetry of the separate and superimposed signals be carefully determined. The symmetrical signals were obtained by a systematic way of introducing "leakage"[2] of the correct phase. The success of this procedure was verified by careful photographic analysis of the signals. From the separate symmetric signals of proton and deuteron a series of superimposed signals were calculated for a set of values of Δ, the beat frequency of the proton master oscillator and the deuteron transmittor, $(\Delta=\nu_1/6-\nu_2)$. These calculated curves were then compared with the actual photographs of the superimposed curves to give the results.

* Work supported by grants from the ONR and The Research Corporation.
[1] F. Bloch, E. C. Levinthal, and M. E. Packard, Phys. Rev. 72, 1125–1126 (1947).
[2] F. Bloch, Phys. Rev. 70, 473 (1946).

F1. Cross Sections for the Reaction $T^3(d,n)He^4$ from 1 to 2.5 Mev and its Use as a Neutron Source. R. F. TASCHEK, A. HEMMENDINGER, AND G. A. JARVIS, *Los Alamos Scientific Laboratory*.—Earlier workers[1,2] accelerating tritons have shown that this reaction has a broad resonance centered near 200-kev triton energy and have made measurements to an equivalent deuteron energy of 600 kev. The present measurements are at deuteron energies of 1.0, 1.5, 2.0, and 2.5 Mev, accelerated onto gaseous tritium targets. The differential cross sections between 45° and 135° were measured by observing the alpha-particles from the reaction. Tentative total cross sections are obtained by integration of a function fitting the observations. The techniques used for handling the small quantities of gas and the small gas target will be described. Experience with the reaction as a strong source of monoergic neutrons of 14 Mev when the target is thick, and as a source of variable energy neutrons from 13 to 18.5 Mev when the target is thin will be discussed. The method used for measuring absolute neutron cross sections in the latter energy range by simultaneous observation of the alphas will be given.

[1] Bretscher and French—LA581 and LA582.
[2] Baker, Holloway, Schreiber, and King—LAMS11.

F2. Excitation Functions for (α,n), $(\alpha,2n)$, $(\alpha,3n)$ Reactions on Indium. G. M. TEMMER,* *University of California, Berkeley*.—Excitation curves have been obtained by means of a magnetic lens beta-ray spectrometer for Sb^{118}, Sb^{117}, and Sb^{116} activities; they were produced by alpha-particle bombardment of stacks of metallic indium foils in the Berkeley 60-inch cyclotron with energies up to 37 Mev. The spectrometer built by R. W. Hayward was used because of the difficulty of resolution of the three periods concerned. The 5.1-hour period previously assigned to Sb^{118} [1] was followed by means of a partially converted gamma-ray of 260 kev. The 2.8-hour activity[1] has definitely been assigned to Sb^{117} by the nature of its excitation and contains a highly converted 156-kev gamma-ray, but apparently no positrons. Finally a 60-minute half-life has been found by Calutron analysis and by chemical separation to belong to a new antimony isotope of mass number 116. The latter is found to emit 1.45-Mev positrons as well as a gamma-ray of about 700 kev. The (α,n) process has a threshold at about 13 Mev and rises to a maximum at around 20 Mev. The $(\alpha,2n)$-process sets in at approximately 18 Mev and reaches its peak at about 28 Mev. The $(\alpha,3n)$ reaction starts in the neighborhood of 27 Mev and still rises at the highest beam energy investigated.

* Atomic Energy Commission Predoctoral Fellow.
[1] K. D. Coleman and M. L. Pool, Phys. Rev. 72, 1070 (1947).

F3. Radioactive Isotopes of Rh and Pd. D. T. EGGEN AND M. L. POOL, *The Ohio State University*.—Two new isotopes have been found following cyclotron bombardments of Ru. A 32-minute positron activity has been made by Ru p and Ru d bombardments. Gamma-rays and 1.65-Mev positrons were observed. A 5-hour Rh activity has been produced by Ru(p,n) and Ru(α,p) reactions which decays by emitting x-rays, 0.6-Mev positrons, gamma-rays, and some electrons. Ru K x-rays have been photographed with a curved crystal camera during the decay of the 21-hour Rh^{100} activity. The 21-hour activity also decays by emitting a 1.55-Mev gamma-ray and 25 percent of the time by 1.3-Mev positron emission. The 9-hour Pd^{101} has been made by alpha-bombardment of Ru and decays by emitting a 0.53-Mev positron about 10 percent of the time and by K-electron capture to a 4.7-day Rh activity. The 4.7-day activity, also produced by Ru(p,n) and Ru(α,p) reactions, decays by K-electron capture, as seen by x-ray photographs, and the emission of 80- and 130-kev gamma-rays, as determined by electron photographs of the internally converted gammas. Equal bombardments with alpha-particles show that the 2.8-day Ru^{97} is produced from $Mo^{94}O_3$ and $Mo^{95}O_3$* by (α,n) and

(α,2n) reactions, respectively, with a relative cross section of 45:1.

* Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation through the Isotope Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

F4. Radioactive Silver Isotopes Produced by Photo-disintegration of Cadmium.* R. B. DUFFIELD AND J. D. KNIGHT, *University of Illinois.*—We have observed that several radioactive silver isotopes are produced when cadmium is irradiated with 20-Mev betatron x-rays. Two of these are well-known isotopes, 7.6-day Ag^{111} and 3.2-hour Ag^{112}. In addition we have found that two other periods, 5.3 hours and 20 minutes, are produced in comparable yield. By the use of a sample enriched in Cd^{114} it has been found that the 5.3-hour activity is to be assigned to Ag^{113}. It decays by the emission of 2.0±0.2-Mev beta-rays. Similarly, using a sample enriched in Cd^{116}, the 20-minute period has been assigned to Ag^{115}. It decays by the emission of 3.0±0.2-Mev beta-rays. No gamma-rays have been observed in either case. It has recently been reported that isotopes of similar half-lives and beta-ray energies have been observed among the uranium fission products.[1,2]

* Assisted by the joint program of the ONR and AEC.
[1] W. Seelman-Eggebert and F. Strassman, Zeits. f. Naturforschung 2a, 80 (1947).
[2] A. Turkevich, Plutonium Project Report ANL-4010 quoted by Seaborg and Perlman in UCRL Report No. 179, dated August 1948.

F5. Angular Distribution of 14-Mev Neutrons Scattered by Deuterons. J. H. COON, R. F. TASCHEK, AND S. G. FORBES, *Los Alamos Scientific Laboratory.*—Monoergic 14-Mev neutrons produced by bombarding a thick tritium target with 220-kev deuterons have been scattered from deuterium in a thin heavy wax radiator and the resulting deuteron recoils counted in double and triple coincidence as a function of scattering angle. Measurements with different gas pressures, counter geometries, and an absorbing foil show that there are no disintegration protons of energies greater than about 3.0 Mev to within about 5 percent of the number of particles observed between 0° and 90° in the laboratory system; the 5 percent observed could be accounted for by ordinary hydrogen contamination recoils. The distribution in number of recoil deuterons per unit solid angle has been measured at seven angles ranging from 0° to 55° in the laboratory system. The laboratory distribution with 7° geometrical resolution shows a rapid drop by a factor of 7 in going from 0° to 30° and a less rapid rise in going from 30° to beyond 55°. A geometrical resolution of 3.5° shows that the factor between 0° and 30° is greater than 7. The center of mass angular distribution will be shown.

F6. Neutron-Proton Scattering.* R. CHRISTIAN AND E. W. HART, *University of California, Berkeley.*—We have calculated the $n-p$ scattering including tensor forces for various potentials. The small angular asymmetry in the 90-Mev experiments[1] indicates that at least 95 percent of the total cross section comes from the S and D states. This necessitates an exchange factor of the form $(1-a+aP_x)$ with $a\sim\frac{1}{2}$. (The more usual "charged" and "symmetrical" dependence are unacceptable.) The best fit is obtained with the meson potential with range 1.25±0.10 $\times 10^{-13}$ cm and $a=0.50$–0.55. There is little distinction between the meson, gauss and exponential potentials, all of which overestimate the high energy cross section by 20 percent. The central force square well gives lower cross sections; however, the introduction of tensor forces increases the scattering at 90 degrees to such an extent that the total is also too high. Scattering from the meson potential including tensor forces is only slightly different from that of the corresponding central case. The overall agreement (including the 0–25-Mev experiments) with the meson potential is good considering the experimental uncertainties.

* The work described was sponsored by the AEC.
[1] Brueckner, Hartsough, Hayward, and Powell, Phys. Rev., in press; Hadley, Kelley, Leith, Segrè, Wiegand, and York, Phys. Rev., in press.

F7. Camera for $P-P$ Scattering at 32 Mev.* WOLFGANG K. H. PANOFSKY AND FRANKLIN FILLMORE. *University of California, Berkeley.*—A camera has been constructed for exposing nuclear track emulsion plates to protons scattered in H_2 gas from the 32-Mev beam from the linear accelerator. The camera is arranged such that no exit slits are necessary. The angular range of scattering angles from 10° to 80° is accessible. Since $p-p$ scattering is symmetrical about 45°, this large angular range permits an internal check against the effect of impurities and background. The geometry is such that the number of tracks per unit solid angle interval in the center of mass system is directly proportional to the differential cross section in the center of mass system, without any angular factors. The proton beam is collimated to a diameter of $\frac{1}{16}''$, then passed through the camera containing up to twenty $1''\times 3''$ Nuclear plates and is then integrated. The plates are arranged symmetrically in order to minimize the required accuracy of the centering of the beam. Background and symmetry studies are in progress and appear satisfactory.

* This work was sponsored by the AEC.

F8. Apparatus for Measuring Proton-Proton Scattering at 32 Mev Using Proportional Counters.* B. CORK, L. JOHNSTON, AND C. RICHMAN. *University of California, Berkeley.*—The linear accelerator is well adapted to proton-proton scattering experiments because of its well-collimated and mono-energetic beam (0.1° angular spread, 0.3 percent energy spread). The scatterer used is hydrogen gas at one atmosphere, the scattering region being roughly a cylinder 0.5 cm in diameter and 2 cm long. Seven proportional counters shaped as annular rings record scattering at 15°, 21°, 27°, 33°, 39°, 45°, 51° (laboratory system) simultaneously, with a possibility of getting a 90° coincidence check between 45°–45° and 39°–51° counters. The annular shape provides a maximum solid angle for the counters. In this way scattering experiments can be done with currents $\sim 10^{-11}$ ampere of collimated protons. Scattering from contaminating gases is minimized by continuously flushing pure hydrogen from a palladium tube through the system, the gas entering at the scattering region. A large background was experienced due to energetic neutrons, generated by 32-Mev protons striking the collimating slits; this has been reduced to less than 10 percent of the counting rate by a rearrangement of slits and absorbing material. The measurements may eventually be extended down to 5°. Some preliminary results will be discussed.

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

F9. Elastic Scattering of 90-Mev Neutrons. A. BRATENAHL, R. H. HILDEBRAND, C. E. LEITH, AND B. J. MOYER, *University of California, Berkeley.*—An experiment to determine the differential cross sections at various angles for elastic scattering of 90-Mev neutrons by C, Al, Cu, Ag, and Pb nuclei will be described. A comparison will be made between measurements using two types of neutron detectors; pieces of carbon activated by the $C^{12}(n,2n)C^{11}$ reaction (20.5-Mev threshold) and a recoil proton counter (60-Mev threshold). This comparison provides a measure of the error due to detection of inelastically scattered neutrons. Elastic scattering cross sections are obtained by integration of the differential cross sections. These scattering cross sections will be compared to total cross sections determined by attenuation measurements using the same detectors.

* The work described was sponsored by the AEC.

F10. Analysis of Low Energy Proton-Proton Scattering Experiments.* G. F. CHEW AND M. L. GOLDBERGER. *University of California, Berkeley.*—From the proton-proton scattering experiments at Minnesota and Wisconsin[1,2] one finds an "effective range[3]" for the nuclear force of $2.61\pm0.02\times10^{-13}$ cm and a scattering length $7.657\pm0.013\times10^{-13}$ cm. The exact interpretation of these numbers in terms of a particular shape for the potential generally involves extensive numerical calculations. However, the variational formulation of the problem[3] shows that the nuclear phase shift depends only on the wave function in the region of strong nuclear potential. Since the coulomb field is here relatively unimportant, it may be treated as a perturbation. This will be true regardless of the proton energy, and the analysis is greatly simplified since coulomb functions need not be used. The results for square and Yukawa wells, respectively, are: Ranges = 2.61 and 1.16×10^{-13} cm (±1 percent); Depths = 13.27 and 47.94 Mev (±0.2 percent). Similar calculations in connection with experiments at higher energies will also be discussed.

* The work described was sponsored by the AEC.
[1] Blair, Freier, Lampi, Sleator, and Williams, Phys. Rev. **74**, 553 (1948); C. L. Critchfield and D. C. Dodder, Phys. Rev. (to be published).
[2] G. Breit, H. M. Thaxton, and L. Eisenbud, Phys. Rev. **55**, 1018 (1939); Herb, Kerst, Parkinson, and Plain, Phys. Rev. **55**, 998 (1939).
[3] J. Schwinger, Phys. Rev. **72**, 742 B11 (1947); J. M. Blatt, Phys Rev. **74**, 92 (1948).

G1. The Energy Spectrum of Mesotron Decay Electrons.* ROBERT B. LEIGHTON, CARL D. ANDERSON, AND AARON J. SERIFF, *California Institute of Technology.*—Electrons from the decay of slow mesotrons at sea level are being studied by means of a freely falling cloud chamber of 30-cm inside diameter and 11-cm depth operating in a magnetic field of 7250 gauss. Slow particles are selected by means of a double coincidence counter telescope, the lower counter of which is inside the cloud chamber, and a tray of anticoincidence counters below the cloud chamber. The counter inside the chamber is rectangular in shape and has a flat top and bottom. This counter is also used as an absorber for the determination of the mesotron mass by measurements of the momentum of the mesotron before and after it traverses the known amount of material in the counter. A plate of carbon 1 cm thick in the lower half of the cloud chamber provides an additional absorber for mesotron mass measurements and for the observation of decay electrons. About one in two hundred photographs show decay electrons, corresponding to about one decay electron per day. To date, over fifty decay electrons have been observed, with energies ranging from about 10 Mev to about 50 Mev, with an apparently continuous distribution of intermediate energy values. The correction for instrumental selection is negligible except for electron energies below about 10 Mev.

* This work was supported in part by the joint program of the ONR and the AEC.

G2. The Decay Products and the Mass of the Mesotron.* CARL D. ANDERSON, ROBERT B. LEIGHTON, AND AARON J. SERIFF, *California Institute of Technology.*—The measurements reported in the previous abstract lead to the following conclusions: (1) The decay electron energy spectrum appears continuous in the range 10 Mev to 50 Mev, and cannot correspond either to a unique electron energy or to a set of two discrete "lines" as, e.g., at 25 Mev and 40 Mev. (2) Those cases in which the decay electron energy and the mesotron mass have been measured for the same mesotron show that these quantities do not bear the relationship to one another to be expected on the basis of conservation of momentum and energy if the mesotron decays simply into a single electron and a single particle of low mass (neutrino). Thus the observed spread in energy of the decay electrons is not to be ascribed to a corresponding range of different mass values of the mesotron. (3) The decay electron spectrum is consistent with the assumption that mesotron decay results in the production of one electron and two neutrinos. On this view, the mass of the mesotron computed for the highest energy decay electron so far observed is 210 ± 10 Mev.

* This work was supported in part by the joint program of the ONR and the AEC.

G3. On Nuclear Capture of Negative Mesotrons.* AARON J. SERIFF, ROBERT B. LEIGHTON, AND CARL D. ANDERSON, *California Institute of Technology.*—In the series of photographs made with the 12″ freely falling cloud chamber, one case has been observed in which a negative mesotron comes to rest in the gas of the cloud chamber without the production of a decay electron. Several small blobs of ionization which are observed a few mm from the end of the mesotron track are interpreted as tracks of photoelectrons which result from the absorption in the gas of soft x-rays which are produced as the mesotron approaches an argon nucleus prior to its capture by the nucleus. No charged particles are emitted from the nucleus after capture of the mesotron. A blob 1.5 mm long at the end of the mesotron track may represent the recoil of the nucleus after the emission of one or more neutral particles. If a single neutron were emitted, its energy could not have been greater than 25 Mev.

* This work was supported in part by the joint program of the ONR and the AEC.

G4. Secondary Particles from Various Nuclei Bombarded with 90-Mev Neutrons.* HERBERT F. YORK, *University of California, Berkeley.*—The $H\rho$'s and ranges of the secondary particles from C, Cu, and Pb bombarded with neutrons of 90-Mev mean energy have been measured simultaneously by means of a magnetic field and proportional counter telescope arrangement. Both protons and deuterons have been found with energies extending from 25 Mev (the present lower limit of the apparatus) to 100 Mev. In the case of carbon the ratio of deuterons to protons in the forward direction is about 2:3, with both energy distributions showing a broad maximum in the region of 50–60 Mev. All particles are peaked forward—deuterons more so than protons and high energy particles more so than those of low energy. The total cross section of carbon for producing deuterons of more than 25 Mev is surprisingly large, being a few hundredths of a barn. The cross section per proton in the carbon nucleus for this process is thus of the order of one-tenth of the total $n-p$ cross section at 90 Mev. For Cu and Pb the ratio of deuterons to protons in the forward direction is less, being approximately 1:3 and 1:6.

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

G5. Recoils of Active Fluorine[18] from 184-in. Cyclotron Bombardment. WARREN EHCKROTTE AND HUGH BRADNER, *University of California, Berkeley.*—F^{19} has been bombarded with high energy neutrons from the 184-in. cyclotron, and an angular distribution and range in Be has been obtained for the resultant F^{18}. The angular distribution shows a pronounced forward maximum:

Angle	Relative activity
0°– 10°	100±15%
5°– 25°	140±15%
20°– 40°	105±15%
35°– 55°	85±15%
80°–100°	10±10%
90°–180°	5

The range, measured by counting the 112-minute activity on a stack of 0.19-mg/cm² Be foils, was 0.8 mg/cm². The interpretation of this distribution with respect to nuclear models will be discussed.

* This work was sponsored by the AEC.

G6. Photographic Plate Confirmation of High Energy Deuterons from 90-Mev Neutrons on Carbon.* H. BRADNER, *University of California, Berkeley.*—In measuring ranges of "protons" knocked out of a carbon target by 90-Mev neutrons, H. York[1] obtained an energy distribution at 10° which had a maximum at 40 to 50 Mev, rather than the 75 Mev predicted theoretically. K. Bruchner and W. Powell[1] re-examined cloud-chamber pictures in which they had obtained $H\rho$ of secondary "protons" from 90-Mev neutrons. Their energy distribution did not agree with theory or with York's experiment. "Proton" energies up to 130 Mev were calculated, but errors from $H\rho$ measurement were large. York pointed out that the two experiments could be reconciled if some of the ions were deuterons of approximately 60 Mev. Further experiments were undertaken with both types of apparatus, and with photographic plates. In the photographic plate experiment, 100 μ emulsion Ilford C-2 plates were set edgewise at 10° to a thin carbon target which was in the neutron beam outside the cyclotron shielding. Grain counts of tracks beginning at the edge of the plates and ending in the emulsion showed definitely that there were high energy deuterons. (Of the 35 tracks counted, 20 were protons, 15 were deuterons.) The measured deuteron energies ranged from 23 Mev to 70 Mev.

* This work was sponsored by the AEC.
[1] Unpublished work.

G7. Inelastic Scattering of Protons.* C. LEVINTHAL, E. A. MARTINELLI, AND A. SILVERMAN, *University of California, Berkeley.*—A photographic method is used to measure the energy distribution of inelastically scattered protons. The 32-Mev linear accelerator is used as a source of protons. Eight plates are exposed simultaneously at fixed polar angle, and the track lengths from 0–200 microns are measured on each plate. With appropriate aluminum absorbers between the target and each plate, the energy distribution from 0–16 Mev or 16–28 Mev can be determined in one run. To determine the energy resolution of the camera, an exposure was made with 16-Mev protons on carbon. The following energy levels of C^{12} were observed: 0; 4.8±.2; 10.0±.4 Mev. This confirms results obtained by Fulbright and Bush.[1] The width of the levels at half-maximum were of the order of 1.0 Mev. The calculated width at half-maximum with the beam stopped down to 16 Mev is 0.7 Mev, considering only straggling in the various absorbers, and the initial spread of the beam. Results obtained by bombarding aluminum with 32-Mev protons will be reported.

* This work was performed under the auspices of the AEC.
[1] H. W. Fulbright and R. R. Bush, Phys. Rev. **74**, 1323 (1948).

G8. On the Injection of Ions in the Bevatron.* R. L. GLUCKSTERN AND LLOYD SMITH, *University of California, Berkeley.*—A serious problem in the operation of a bevatron is to insure that the ions will not strike the injector during the acceleration period. Since the adiabatic damping is negligible during the injection period, it has been proposed to allow the ions to spiral into the center of the chamber before turning on the accelerating voltage. The question is then whether or not the betatron oscillations will enable the ion to clear the injector while the instantaneous circle moves inward. We have investigated the probability of an ion being in the neighborhood of the injector on successive turns for various amplitudes of betatron oscillation and for various shapes of magnetic fields. Our conclusion is that for the proposed machine only $\frac{1}{4}$ of the ions will be lost in this manner. This result was corroborated by tracing some actual ion paths. Apparently, no electromagnetic orbit contracting device will be necessary.

* This paper is based on work done under the auspices of the AEC.

G9. Production Ratio of Positive and Negative Mesons for Various Cyclotron Target Materials.* WALTER H. BARKAS,** *University of California, Berkeley.*—A study has been made to find the relative numbers of positive and negative mesons produced in various target materials by a beam of 380-Mev alpha-particles. Photographic plates to record positive and negative mesons were placed[1] symmetrically on opposite sides of the target in the 184-inch

Berkeley cyclotron. Although the energy range over which mesons are accepted is not well defined, it is the same for both positives and negatives. The area scanned is such that no mesons are counted of energy less than 2 Mev, and few, if any, have energies higher than 5 Mev. The photographic plates used were Ilford types C.2 and C.3, with emulsion thickness 100 microns. Cyclotron targets were $\frac{1}{64}$ inch thick. Observations were made using targets of Be, C, Al, Cu, In, and Pb. The survey indicates: (1) the production of negative mesons in the energy interval studied does not vary rapidly with atomic number, and (2) the ratio of positive to negative mesons, which is about $\frac{1}{5}$ for carbon, falls virtually to zero for heavy elements.

* This paper is based on work performed with the support of the AEC.
** Office of Naval Research, San Francisco, California.
[1] J. Burfening, E. Gardner, and C. M. G. Lattes, Phys. Rev. **75**, (1949).

G10. Meson Mass Measurements. Part I. Experimental Method.* EUGENE GARDNER, *University of California, Berkeley*.—A new determination is being made of the masses of mesons produced by 380-Mev alpha-particles in the 184-inch Berkeley cyclotron. The method, that of bending in the magnetic field and range in emulsion, is similar to that used in an earlier determination,[1] except that several changes have been made in order to increase the accuracy. In addition to improvements associated with more precise positioning of plates and more careful measurement of distances, the following changes have been introduced: (1) the plates used in the present study were exposed in the cyclotron without wrapping. This procedure avoids the energy loss and scattering of the mesons in the black paper or aluminum foil wrapping. (2) Only those mesons which leave the target moving approximately in the direction of the alpha-particle beam are used; the mass value can be determined most accurately for these mésons. The selection is automatically made by means of a "channel" which admits only a narrow angular spread of meson trajectories. (3) The plates are inclined to the meson trajectories in such a way that the mesons enter the emulsion through the top surface. In this way errors associated with the distortion at the edge of the plate are avoided.

* This paper is based on work performed with the support of the AEC
[1] E. Gardner and C. M. G. Lattes, Science **107**, 270 (1948).

G11. Meson Mass Measurements. Part II. Experimental Results.* A. S. BISHOP, *University of California, Berkeley*.—Preliminary values for the meson masses are: heavy negative meson: $285m_e$, heavy positive meson: $286m_e$, light positive meson: $216m_e$, where m_e is the mass of the electron. When this study is completed, it is hoped that the probable error will be as low as 2 percent. The preliminary values given above, however, have an additional uncertainty of one or two percent since several small corrections have not yet been made. The ratio of masses of heavy positive to light positive mesons is 1.32 ± 0.01. This ratio is known to greater accuracy than the masses themselves because the error in the measurement of the magnetic field is largely eliminated. The method of measuring meson masses by $H\rho$ and range is being checked by measuring the proton mass, using the same method. For a range-energy relation in the emulsion (Ilford C.2) we have used a curve obtained by extrapolating to higher energies from the points given by Lattes, Fowler, and Cuer.[1] We hope to verify this curve by means of exposures to protons from the Berkeley linear accelerator.

* This paper is based on work performed with the support of the AEC.
[1] C. M. G. Lattes, P. H. Fowler, and P. Cuer, Proc. Phys. Soc. **59**, 883 (1947).

G12. Meson Mass Measurements. Part III. Discussion of Results.* C. M. G. LATTES,** *University of California, Berkeley*.—The value found in this study for the ratio of masses of heavy and light positive mesons is consistent with the assumption that a light particle (e.g., a neutrino or a gamma-ray) is emitted when a heavy positive meson decays into a light positive one. From studies of negative mesons in which there was a channel between the target and the plates, it is concluded that few, if any, light negative mesons come from the target. From similar studies of positive mesons it is concluded that light positive mesons do originate at the target; their energy spectrum indicates that they come from the decay of heavy positive mesons which stop in the target. By combining the results of the present study with an earlier measurement of the meson mass by grain counting,[1] it is possible to show that the magnitude of the charge on the meson is equal to that on the electron within the accuracy of the measurements. In one group of heavy positive mesons it was observed that 54 out of a total of 59 gave observable secondary mesons. This result indicates that any competing process (such as the decay of the heavy meson into an electron and a neutrino) must have a longer half-life.

* This paper is based on work performed with the support of the AEC.
** On leave of absence from University of São Paulo, Brazil.
[1] W. H. Barkas, E. Gardner, and C. M. G. Lattes, Phys. Rev. **74**, 1558 (1948).

H1. Stars in Photographic Emulsions Initiated by Heavy Negative Mesons.* FRANK L. ADELMAN AND STANLEY B. JONES, *University of California, Berkeley*.—We have tabulated the number of prongs (charged particle tracks) per star for stars initiated by heavy negative mesons in photographic emulsions. The mesons were created in the 184-inch Berkeley cyclotron by bombarding a target with 380-Mev alpha-particles. The mesons used in this study were found to be heavy by the method of $H\rho$ and range. The following table gives the prong distribution for 588 stars.

Number of prongs:	0	1	2	3	4	5	Over 5
Percent of stars:	27.0	23.6	24.0	14.8	8.7	1.9	0

In no case was a heavy negative meson observed to decay into a light negative meson ($\pi-\mu$ decay). Eleven "hammer tracks" were found in a survey of about 3000 stars. These are explained[1] as follows: a Li^8 nucleus, emitted in a nuclear reaction, undergoes β-decay into Be^8, which then splits into two alpha-particles of equal energy.

* This paper is based on work performed with the support of the AEC.
[1] C. Franzinetti and R. M. Payne, Nature **161**, 735 (1948).

H2. Yield of Negative Mesons Produced by High Energy Alpha-Particles as a Function of Alpha-Particle Energy.* STANLEY B. JONES AND R. S. WHITE, *University of California, Berkeley*.—A study is now in progress to find the relative numbers of negative mesons created by alpha-particles of various energies. The various energies are obtained at different radii in the 184-inch Berkeley cyclotron. The study first included only mesons in a particular energy interval of the order of 2–5 Mev. The intensity of the mesons in this energy interval *versus* the bombarding beam energy is given in the accompanying table. Column 1 gives the energy of the bombarding alpha-particles; column 2, the numbers of mesons actually counted; and column 3, the numbers of mesons relative to the number at 380 Mev, corrected for beam currents, plate thickness, and area scanned.

Beam energy (Mev)	No. of mesons	Corrected relative yield
380	339	100 percent
342	164	33 percent
304	38	7.4 percent
266	7	0.7 percent

The exposures were made with a carbon target and with Ilford type C.2 plates. The plates were scanned over a region estimated to include about 90 percent of the mesons in each plate.

* This paper is based on work performed with the support of the AEC.

H3. Excitation Functions from Deuteron Bombardment of Cu. D. Bockhop, A. C. Helmholz, S. D. Softky, J. W. Rose, and T. Breakey, *University of California, Berkeley.*—Excitation functions have been measured of Zn, Cu, Ni, and Fe from Cu bombarded by 190-Mev deuterons produced by the 184-in. cyclotron. The deuterons are incident on a stack of Cu plates which has Cu foils spaced through it at equal energy intervals, and quantitative chemical separation of the products from the foils gives the relative yield as a function of the energy. The absolute yield at 190 Mev is compared with that of Na^{24} from a thin Al foil[1] at this energy, thus determining cross sections from formation as a function of energy. The yields for Mn^{52}, Mn^{56}, Fe^{59}, and Co^{58} increase with increase of energy, while those of Zn^{62}, Zn^{63}, and Cu^{64} show maxima at low energies and then decrease with energy. Cross sections of the order of that of Na^{24} from Al are obtained for Cu and Zn, but only of the order of one-tenth of that of Na^{24} for Fe and Co. Results obtained to date agree well with previous work done on deuteron bombardment of Cu at this laboratory,[2] and it is indicated[3] that excitation curves may well be obtained for elements even further below Cu.

* The work described was sponsored by the AEC.
[1] H. W. Hubbard, see abstract H7.
[2] D. Bockhop, A. C. Helmholz, and J. M. Peterson, Phys. Rev. **74**, 1559 (1948).
[3] D. R. Miller, R. C. Thompson, and B. B. Cunningham, Phys. Rev. **74**, 347 (1948).

H4. Radio activities of Ag^{111}, Cd^{111}, and In^{111}.* A. C. Helmholz, R. W. Hayward, and C. L. McGinnis, *University of California, Berkeley.*—We have investigated with a magnetic lens spectrograph built by one of us (R.W.H.) the three isobaric activities, Ag^{111}, Cd^{111}, and In^{111}. The second of these is the 48.6±0.3-min. isomer of stable Cd^{111}. It emits a highly converted 149-kev γ-ray and a 247-kev γ-ray of conversion coefficient 0.1. The latter is the same as that observed[1] in the *K*-capture decay of the 2.84±0.03-*d*. In^{111}. Emitted in coincidence[2] in the In^{111} decay is a 173-kev γ-ray with conversion coefficient 0.18. From these data Cd^{111} has three excited states at 247, 396, and 420 kev. Using the theory of Hebb and Nelson[3] and the *K*/*L* ratios, we find the 247-kev γ-ray is magnetic quadrupole, the 173 electric quadrupole, the 149 electric 2^4 pole. The β^--spectrum of the 7.5-*d*. Ag^{111} was analyzed according to the Fermi theory. It appears to be of simple form with an upper limit of 1.06±0.03 Mev. This is a once forbidden transition according to Konopinski's classification. Difficulties in the formulation of a level scheme point out the need of accurate theoretical conversion coefficients for $Z \sim 50$.

* The work described was sponsored by the AEC.
[1] J. H. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).
[2] H. Bradt, *et al.*, Helv. Phys. Acta **19**, 77 (1945).
[3] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).

H5. Study of Cd^{115} Isomers.* R. W. Hayward** and A. C. Helmholz, *University of California, Berkeley.*—Using a magnetic lens spectrograph of the type constructed by Siegbahn,[1] we have investigated the β-spectrum of the 43-d Cd^{115}, in a sample of Cd obtained from Oak Ridge. The spectrum has an end point at 1.67 Mev and seems to be simple. The 86 kev converted γ-ray of Cd^{109} is also observed. A separate investigation of the other isomer of Cd^{115}, the 2.3-d activity, gave agreement with the work of Lawson and Cork.[2] The spectrum is complex, and has an end point of 1.10 Mev. It shows γ-rays of 337 kev and 520 kev and conversion lines of the 337-kev γ-ray which is due to the 4.5-hr. In^{115} in equilibrium. Thus the 43-d isomer must be the upper state by 0.2 Mev. Since no evidence of such a γ-ray has been found, the γ-transition must correspond to at least a 2^5 and probably a 2^6 pole transition. Possible spin and parity assignments to the levels assuming the ground state of In^{115} is 9/2 and even might be: In (4.5 hr.) 1/2 odd; Cd (2.3 d) 1/2 even; Cd (43 d) 13/2 even. A discussion of possible level schemes will be given.

* The work described was sponsored by the AEC.
** AEC Predoctoral Fellow.
[1] K. Siegbahn, Phil. Mag. **37**, 162 (1946).
[2] J. H. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).

H6. Absolute Cross Section for Production of Heavy Negative Mesons by 380-Mev Alpha-Particles.* Vincent Peterson, *University of California, Berkeley.*—The absolute cross section per atom of target material for production of heavy negative mesons by 380-Mev alpha-particles has been measured for carbon and several other elements of widely different *Z*. Photographic plates were used to detect the mesons, and the flux of alpha-particles was determined by measuring the C^{11} radioactivity produced in a thin polystyrene foil covering the face of the target. The absolute cross section for the reaction $C^{12}(\alpha,\alpha_n)C^{11}$ was also measured to relate C^{11} activity to alpha-current. The solid angle of meson radiation accepted by the photographic plate was calculated from either: (a) emulsion thickness, for edge-on exposure, or (b) tilt angle, for plates inclined slightly to the horizontal. Only mesons entering the plate within ±45° from the normal were counted. Assuming the angular distribution to be spherically symmetric, and a theoretical energy distribution $dN(E)=f(E)(E_m-E)^4E^{\frac{1}{2}}dE$, where $E_m=45$ Mev and $f(E)$ is the Coulomb factor, the absolute cross section for carbon has been calculated to be $(1.8\pm.3)\times10^{-29}$ cm^2. Correction for decay in flight has been made. The plates accept mesons of energies from 2–5 Mev (normal incidence).

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

H7. $Al^{27}(d,\alpha p)Na^{24}$ Cross Section.* H. W. HUBBARD, *University of California, Berkeley* (introduced by A. C. Helmholz).—The cross section for the reaction $Al^{27}\times(d,\alpha p)Na^{24}$ was measured for incident 194-Mev deuterons by means of the deflected deuteron beam from the 184-inch cyclotron at Berkeley. An aluminum foil was bombarded for about one hour, the beam current being measured by means of a Faraday cage system of known capacitance. The number of Na^{24} atoms was then measured by means of beta-gamma coincidences, which is possible since Na^{24} emits two γ-rays in coincidence with each electron.[1] The results obtained in this way agreed closely with those obtained by comparing the active foils with a uranium β-standard. The best result from four independent measurements gives a value for the cross section at 194 Mev of 0.048 barn, the result probably being accurate to 15 percent.

* The work described was sponsored by the AEC.
[1] M. L. Wiedenbeck, Phys. Rev. **72**, 429 (1947).

H8. Nuclear Cross Sections for 90-Mev Neutrons.* N. KNABLE, J. DE JUREN, AND B. J. MOYER, *University of California, Berkeley.*—Using bismuth fission chambers (threshold about 50 Mev) to monitor and detect high energy neutrons produced in the 184-in. cyclotron, total cross sections for twelve different elements were measured. The mean detection energy is estimated at 95 Mev. The hydrogen cross section result was 0.073 ± 0.002 barn, and the deuterium-hydrogen difference was determined to be 0.031 ± 0.002 barn. An arrangement giving simultaneous measurements of neutron attenuation with both good and poor geometry has given values for the ratios of inelastic to total cross sections for various elements lying between 0.4 and 0.5. An absolute measure of the elastic scattering cross section in the case of carbon was in good agreement with that deduced from the total and inelastic values. A plot of inelastic collision radius *vs.* $A^{\frac{1}{3}}$ shows the same slope as the plot of total collision radius in the region of high atomic number where transparency effects become unimportant.

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

H9. High Energy Gamma-Radiation from 184-Cyclotron Target.* B. J. MOYER, H. F. YORK, AND R. BJORKLUND, *University of California, Berkeley.*—An electron pair counter has been assembled, utilizing a magnetic field to separate the pairs, and coincidence counting to detect them. A radiator of thin Ta serves to materialize the photons. This is exposed to the cyclotron target from outside the shielding, through the neutron beam defining hole. The direction of rotation of the deuteron beam is reversed to minimize the background counting due to effects from neutrons. In any of the targets used (Be, Cu, Pb) photons were observed in distributions extending to at least 70 Mev. An energy distribution for Be will be shown, corrected for variation in pair production probability, variation in energy breadth detected, and effects due to scattering of the pair electrons. For a mean detection energy of 50 Mev the integrated cross section for production of photons in the energy breadth detected (approximately 40–60 Mev) is about 10^{-30} cm^2. This value and the distribution with respect to energy are reasonably consistent with a bremsstrahlung origin for the photons.

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

H10. Detection of Very High Energy Protons by Means of Anthracene Scintillation Counters.* L. WOUTERS, *University of California, Berkeley.*—Because of the low ionization density of very high energy protons (as generated in synchro-cyclotrons), the pulses produced in proportional gas counters are all but lost in the competing beta-background. Anthracene scintillation counters can be arranged so that an amount of usefully detectable energy, large compared to the energy of the competing radiation, is abstracted from the protons; no difficulty then exists in sorting these out. The equipment used at the Radiation Laboratory for experimental work at the 184″ site will be described. The most expeditious way of determining the usefulness of the apparatus was to perform an $n-p$ scattering experiment for which reliable results had been established by more orthodox methods; agreement well within the range of the best data of these other methods was obtained. The unique degree of energy discrimination appeared as a broad counting plateau between the proton and the background pulse levels. The percentage of non-coincidence pulses from the individual counters was then relatively small; together with the short radiation time of anthracene, enormously faster counting rates are made permissible, in comparison with gas counters.

* The work described was sponsored by the AEC.

H11. Radiation Field of the 184-Cyclotron.* W. K. BENSON, JR., R. L. MATHER, B. J. MOYER, AND JOSEPH YATER, *University of California, Berkeley.*—The distribution and intensity of the radiation field outside the shielding of the 184″ cyclotron have been studied with various types of detectors. Three-dimensional surveys were made with proton recoil counter, calibrated slow neutron counter, and an ion chamber so constructed as to read approximately the "roentgen equivalent physical" dosage rate. Average values at normal areas of habitation are: 60 slow neutrons cm^{-2} sec.$^{-1}$, 0.5 milli-rep/hr., and a fast neutron flux about an order of magnitude below tolerance. Determination of the actual value for fast neutron flux depends upon energy distribution assumed. Studies of this are in progress. Calibrated indium foil measurements of slow neutron flux as a function of depth in the 10-ft. concrete shielding indicate, apart from transition and boundary effects, an attenuation with a half-value thickness of 7 to 8 inches, and a value at the outside surface in agreement with that mentioned above.

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

H12. Kinetic Energy Release in Fission Induced by High Energy Neutrons.* J. JUNGERMAN AND S. C. WRIGHT, *University of California, Berkeley.*—The ionization produced by single fission fragments was observed in an ionization chamber using electron collection. Fission was induced in bismuth and other substances by 90-Mev neutrons. The distribution of fragment energy *versus* number of fragments has a single peak. This is in contrast to the double peaked curve obtained with thermal neutron fission of U^{235}. For bismuth the most probable single fragment energy is 74 Mev, and the mean fragment energy is 71 Mev.

* The work described was done under the auspices of the AEC.

SUPPLEMENTARY PROGRAMME

SP1. Inelastic Scattering of Protons from Li^7.* W. A. FOWLER, C. C. LAURITSEN, AND S. RUBIN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The energy of the lowest excited state of Li^7 has been redetermined[1] with a double-focusing magnetic spectrograph[2] by measuring the energy of the protons inelastically scattered at angles of 81.1° and 137.8° from lithium bombarded by 1233.5-kev protons. The spectrograph was calibrated by the elastic scattering of protons of the same energy by copper. The scattering angles were carefully measured and checked by elastic scattering in lithium, beryllium, carbon, and oxygen. The bombarding proton energy is stabilized to better than 1 kev by an electrostatic analyzer calibrated at 440 kev with the γ-ray resonance in $Li^7(p\gamma)$. Careful attention was given to loss of energy of the incident and scattered protons in surface layers ($\sim$100 atoms) of carbon and oxygen on the various targets. The scattering observed from these layers indicated a thickness corresponding to an 0.5-kev energy loss for 1-Mev protons incident normally. The final result of this determination is 477.4 ± 2.0 Mev for the excited state in Li^7 and is to be compared with the value 476.8 ± 1.0 found by measurement of the gamma-ray[3] emitted by Li^{7*}. If the gamma-ray measurement is accepted the resonance in $Li^7(p\gamma)$ is located at 439.5 ± 2.3 kev, and the first strong resonance in $F^{19}(p\alpha,\gamma)$ is located at 869.9 ± 4.6 kev.

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

[1] Rubin, Snyder, Lauritsen, and Fowler, Phys. Rev. **74**, 1564A (1948).

[2] Snyder, Lauritsen, Fowler, and Rubin, Phys. Rev. **74**, 1564A (1948).

[3] W. F. Hornyak and T. Lauritsen (unpublished).

SP2. Comets and the Reciprocal Force. F. W. WARBURTON, *University of Redlands.*—Verification of relative electrodynamics may possibly be found in the behavior of comets. Electrical equilibrium of a body receiving ions from the sun[1] and re-emitting ions at the same rate is similar to temperature equilibrium of a body receiving and re-emitting radiation. An increase in the reception of negative ions from the sun as the comet approaches perihelion is believed to augment the normal radiation excitation of atoms and so be related to the rapid variation in brightness of the comet. The relative reciprocal force is a function of the speed of the emitting charge e', and rapid increase in average electron speed in the comet should result in negative ion emission and account for the explosive ejection of matter which forms the comet's envelope and tail. Also radiation pressure can be augmented by the negative ion emission from the sun acting on the ejected matter which forms the tail.

The shift in balance of electrical charge emission in the comet should affect the force of the sun on the comet itself. It is evidently related to the shortening of the period which is so prominent in Encke's comet.

[1] See Abstract No. A2.

SP3. Report of Initial Performance of the Berkeley Synchrotron. E. MCMILLAN, *Radiation Laboratory, University of California, Berkeley.*

SP4. Acceleration of Protons in the 184-inch Berkeley Cyclotron. K. M. MCKENZIE, *Radiation Laboratory, University of California, Berkeley.*

SP5. Neutron Diffraction in Liquid Elements. OWEN CHAMBERLAIN, *University of Chicago.*

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