Minutes of the Stanford Meeting December 28, 29, and 30, 1953

THE 1953 Winter meeting of the American Physical Society was held at Stanford University on Monday, Tuesday, and Wednesday, December 28, 29, and 30, 1953. This meeting turned out to be an unexpectedly large one, in spite of the fact that the Summer meeting in the West had been held in September instead of in June. There were about 300 registrations at this meeting, as compared with 436 at the Albuquerque meeting.

There were two outstanding sessions of invited papers, and accounts of these will appear in *Physics Today*. The experiment of devoting one day to a symposium, with no overlapping sessions, proved to be unusually successful. The Secretary is grateful to Professor Schiff and Professor Bloch for suggesting and arranging the Symposium on Nuclear Magnetism, and to Professor W. P. Dyke for his work in arranging the session of invited papers sponsored by our Division of Electron Physics. Both of these sessions were outstanding and were well attended.

There were no post-deadline papers, but an unusually large number of papers were read by title. These were papers B7, F2, F3, F4, F12, and I10. The Secretary appreciates receiving early notice when papers are to be given by title, but he also feels that those who submit papers should try to give them or to arrange for the papers to be read. It is not fair to those who attend to remove papers after the program has been printed. Paper E4 on the nuclear magnetism symposium was briefly reviewed by Dr. G. E. Pake, because the author was unable to attend.

At the opening of the Monday afternoon session of the Division of Electron Physics, the Chairman, Professor L. B. Loeb, called for a moment of silence as an indication of the respect and admiration that all of us felt for the late Professor R. A. Millikan. Although Professor Millikan was an important member of the world community of scientists, and an important force in the life of this Nation, those of us in the West had particularly personal reasons for regretting his passing. Professor Millikan would have enjoyed the leisurely and stimulating atmosphere of the Stanford meeting, and he will be missed by all of us as we carry on the development of physics in the West, a development to which he gave such a fine impetus.

The Secretary wishes to thank the staff of the Department of Physics at Stanford, and in particular those who made possible the excellent accommodations in the campus living facilities and the excellent meals at the Stanford Union.

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

Errata Pertaining to Papers A3, G6, and SP1

A3, by B. Smaller, E. Yasaitis, and M. Brachman. Mr. Brachman's name was misspelled.

G6, by Ervin C. Woodward, Jr. Cd II$(4d^{10}5p^2P_{3/2}-4d^95S^{22}D_{5/2})$ should read Cd II$(4d^{10}5p^2P_{3/2}-4d^95s^{22}D_{5/2})$.

SP1, by Ervin C. Woodward, Jr. In line 7, prison should read prism.

PROGRAMME

MONDAY MORNING AT 10:00

Physics 370

(W. E. MEYERHOF, presiding)

Contributed Papers

A1. Nuclear Resonance of Nb^{93} in $KNbO_3$.* R. M. COTTS AND W. D. KNIGHT, *Department of Physics, University of California, Berkeley.*—$KNbO_3$ is known to exist in rhombohedral, orthorhombic, tetragonal, and cubic modifications of the perovskite structure. X-ray, optical, and dielectric data[1] show phase transitions at about −50, +220, and +435°C. $KNbO_3$ is ferroelectric[2] below the Curie temperature, 435°C. We have examined the nuclear magnetic resonance spectrum of Nb in a single crystal† and have observed the effects of the transitions on the quadrupole splitting of the spectrum. Our data confirm the three transition temperatures and verify the hysteresis effect seen in the dielectric constant (ϵ) around 220°C. The expected change as the crystal passes from the tetragonal to the cubic phase at 435°C is striking: in the cubic nonferroelectric phase the quadrupole splitting vanishes completely. The splitting ($\Delta\nu$) of the ($\frac{3}{2}$, $\frac{1}{2}$) line from the Larmor frequency is a smoothly varying function between 220° and 435°C. At 435° $\Delta\nu$ falls abruptly from about 100 kcps to zero within a range of 2°C. The data for both $\Delta\nu$ and ϵ indicate that this is a transition of the first order. It is hoped that independent measurements of the Nb quadrupole moment will make it possible to evaluate the crystalline ∇E from the $\Delta\nu$ measured in this experiment.

* Supported in part by the U. S. Office of Naval Research.
[1] E. A. Wood, Acta Cryst. **4**, 353 (1951); Pepinsky, Thakur, and McCarty, Phys. Rev. **86**, 650 (1952); B. T. Matthias and J. P. Remeika, Phys. Rev. **82**, 727 (1951).
[2] B. T. Matthias, Phys. Rev. **75**, 1771 (1949).
† Kindly furnished by the Bell Telephone Laboratories.

A2. Saturation Behavior of a Gaussian Magnetic Resonance Line.* D. F. ABELL† AND W. D. KNIGHT, *Department of Physics, University of California, Berkeley.*—We have extended previously reported work[1] to cover the Gaussian saturation behavior of the derivatives of absorption and dispersion modes, for modulation frequencies both long and short compared to $1/T_1$, where T_1 is nuclear spin-lattice relaxation time. The experimental data for metallic copper have been improved, and more accurate values for T_1 are 7.8 ± 1 and 6.8 ± 1 milliseconds, for Cu^{63} and Cu^{65}, respectively, at 300°K. T_1 shows no dependence on applied dc magnetic field in the region corresponding to resonance frequencies of 2 and 4 mcps. The measured relaxation times are in the expected ratio to each other, but both are about three times longer than free-electron theory[2] predicts. Exchange and correlation effects have been shown to reduce the density of states at the Fermi surface, and the deviations in measured T_1 from predictions of free-electron theory are interpreted as a measure of this reduction. The measured copper line width decreases markedly with increasing saturation, which is contrary to expectation. We are indebted to Dr. C. D. Jeffries and to Varian Associates for the use of apparatus.

* Supported in part by the U. S. Office of Naval Research.
† Now at the University of Nevada, Reno, Nevada.
[1] W. D. Knight, Phys. Rev. **91**, 206 (1953.
[2] J. Korringa, Physica **16**, 601 (1950).

A3. Paramagnetic Resonance of Mn^{++} at Radiofrequencies. B. SMALLER, E. YASAITIS, AND M. BROCHMAN,* *Chemistry and Physics Divisions, Argonne National Laboratory.*—Studies on the paramagnetic resonance of the Mn^{++} ion in the radiofrequency range 10 to 500 Mc reveal a single line with a g value near unity, in agreement with $I=J=5/2$. The line shape is best fitted by a Gaussian distribution throughout the range while the line width reaches a minimal value of about 6 gauss rms at low frequency, high temperature, and low concentration. The effect of neighboring dipole ions can be evaluated as can the "motion narrowing" contribution. The residual line width must then be assumed to be due to transitions between magnetic substrates of low total quantum number, F. Since the dependence of g on frequency corresponds to an $F=5$ or 4 state, the transitions in the low F states apparently become rapidly forbidden with increasing frequency. An interesting effect occurs where the resonant field strength is less than the line width. The resonance shows an anamolous broadening which can be explained in terms of contributions existing at negative values of the external field.

* Present address: Texas Instruments, Inc., Dallas, Texas.

A4. Temperature Dependence of the Nuclear Resonance Shift in Metals.* B. R. MCGARVEY AND H. S. GUTOWSKY, *University of Illinois.*—The temperature dependence of the nuclear resonance shift in metals has been investigated in lithium, sodium, rubidium, cesium, and gallium. The resonance shifts were found to change by no more than 5 to 6 percent over temperature ranges of 200°, including the melting point. For sodium, the observed temperature dependence of the resonance shift is correlated directly with the volume dependence predicted theoretically for the mass magnetic susceptibility due to the conduction electrons. In the other metals, effects appear which are related apparently to the volume dependence of the wave functions for electrons at the top of the conduction band. The room temperature resonance shifts of Sn^{117} and Sn^{119} and the temperature dependence of the Rb^{87} line width will also be reported upon.

* Supported in part by the U. S. Office of Naval Research.

A5. Nuclear Resonance of P^{31} in CS_2 Solutions.* BROTHER SIMON PETER, F. S. C.,† *University of California, Berkeley.*—A concentration-dependent shift of the P^{31} nuclear magnetic resonance frequency has been observed in solutions of white phosphorus in CS_2. For a given fixed external field the resonance frequency is lower for a more dilute solution. The frequency shift relative to pure white phosphorus varies approximately linearly with the mole fraction of phosphorus in the solution for the mole fraction range of from 0.02 to 1.0. Extrapolated to infinite dilution, the measured relative shift is $(5.3\pm0.7)\times10^{-5}$. The solutions were made and used under water. The measuring apparatus included a Pound recording spectrometer and a permanent magnet which provided a field of 7300 oersteds. Samples were interchanged in the same position in the field. The observed effect is ascribed to an interaction of the dissolved phosphorus with the solvent. Other experiments, to be reported elsewhere, on a large number of phosphorus compounds, have been analyzed in terms of additive partial shifts for each atom bonding to phosphorus. Each of these partial shifts turns out to be diamagnetic, and it is then to be expected that, since solvation effects increase with increasing dilution, the local magnetic field at the phosphorus nucleus would also decrease. Possible effects of chemical association among the P molecules will be discussed, as well as possible effects of the bulk susceptibility of the solutions.

* Supported in part by the U. S. Office of Naval Research.
† Now at Saint Mary's College, California.

A6. Experiment for Measurement of the Magnetic Moment of the Neutron.* VICTOR W. COHEN AND NOEL R. CORNGOLD, *Brookhaven National Laboratory*, AND NORMAN F. RAMSEY, *Harvard University*.—An experiment is being performed to make a determination of the ratio of magnetic moments of the neutron to proton, to a greater precision than has heretofore been attained. The method is somewhat similar to that used by Bloch and co-workers[1] and the atomic beam resonance method with separated oscillatory fields.[2] The slow neutrons are highly polarized by reflection at small glancing angles from a magnetized colbalt mirror. These will be reflected from a second analyzing mirror. Between the mirrors, the neutrons pass a region of uniform permanent magnetic field where they may become depolarized by a resonant rf magnetic field. This will result in a decrease in neutron beam intensity reflected from the second mirror. The ratio of the neutron resonance frequency to that of a proton field probe gives the ratio of the magnetic moments. In order to achieve high precision, the path in the magnetic field is about 150 cm. The separated oscillatory field method[2] is used to average the magnetic field along the path of the neutron and thereby to obviate the need for great uniformity. The path length between loops is long enough to give a natural line width for the neutron resonance of about 1 part in 25 000. The magnetic field is explored point-by-point with a small proton resonance probe. Rough preliminary results are in agreement with previous investigators.[1]

* Work carried out under contract with the U. S. Atomic Energy Commission.
[1] Bloch, Nicodemus, and Staub, Phys. Rev. **74**, 1025 (1948).
[2] N. F. Ramsey, Phys. Rev. **78**, 695 (1950).

A7. Free Nuclear Induction in the Earth's Magnetic Field. MARTIN PACKARD AND RUSSELL VARIAN, *Varian Associates*.—Free nuclear induction signals have been observed in the earth's magnetic field. The very simple experimental apparatus does not use a rotating magnetic field but relies on a polarizing field to preorient the magnetic moments at right angles to the earth's field. The polarizing field of about 100 gauss is left on for a time longer than T_1 after which it is reduced to zero rapidly enough to satisfy the nonadiabatic conditions, leaving the moments perpendicular to the earth's field. The precession of the magnetic moments about the homogeneous earth's field at a frequency of 2185 cycles is observed as a voltage induced in a receiver coil oriented perpendicularly to both the earth's field and the polarizing field. The free induction signal from 500 cc of water is observed to persist for a time greater than one second. This free decay time is probably determined by an instrumental T_2 rather than by the real T_2 of the water. A sample of HF shows a beat pattern which occurs at a frequency of about 120 cycles which is compatible with the difference in γ for hydrogen and fluorine. The absolute value of the earth's field can be easily measured by measuring the precessional frequency. The present signal-to-noise of 20 is adequate to permit a measurement of the earth's field to about one part in 15 000.

A8. Measurement of Nuclear Induction Relaxation Times in Weak Magnetic Fields. ARNOLD BLOOM AND DOLAN MANSIR, *Varian Associates*.—The spin-lattice and spin-spin relaxation times of nuclear magnetic moments in weak magnetic fields (of the order of the earth's magnetic field) have been measured through the use of the free precession apparatus described in the previous abstract. To measure T_1 in very weak fields the polarizing field is reduced at $t=0$ from its initial value of about 100 gauss to a residual value of about 2 gauss. The residual field is then removed at $t=\tau$ and the resulting free precession signal has an initial amplitude proportional to $\exp(-\tau/T_1)$. By varying τ, T_1 can be measured. T_2 can be determined directly from the time decay of the signal if the earth's field is homogeneous. If the earth's field is not homogeneous, a form of spin-echo technique can be employed for measuring T_2. In this technique a short pulse of inhomogeneous polarizing field is applied at $t=\tau$, following the initial removal at $t=0$. At $t=2\tau$ a spin echo occurs whose amplitude, under certain conditions, is proportional to $\exp(-2\tau/T_2)$ and is independent of the amplitude and duration of the polarizing field pulse. Experimental results will be discussed.

A9. Isotopic Spin and Odd-Odd $N=Z$ Nuclei.* S. A. MOSZKOWSKI† AND D. C. PEASLEE, *Columbia University*.—The recent discovery of a $T=1$, $J=0$ ground state[1] in Cl^{34} provides the first known exception to the usual expectation that a nuclear ground state has the minimum isotopic spin possible; e.g., $T=0$ for an odd-odd $N=Z$ nucleus. The position of the lowest $T=1$ state of an odd-odd $N=Z$ nucleus relative to the $T=1$ ground state of the neighboring even-even $N=Z+2$ isobar can be estimated theoretically and is in fair agreement with experimental data. For the lightest odd-odd $N=Z$ nuclei, H^2 to Na^{22}, the ground state has $T=0$. However, the energy difference between the lowest $T=0$ and lowest $T=1$ state decreases with increasing A. The known positron emitting states of Al^{26}, P^{30}, and K^{38} appear to have $T=1$, 0, and 0, respectively. Tentative predictions regarding the decay of the lowest $T=1$ state in Na^{22} and K^{38} and the decay of the lowest $T=0$ state in Al^{26} will be presented.

* Work supported by the U. S. Atomic Energy Commission.
† Now at University of California, Los Angeles, California.
[1] W. Arber and P. Stähelin, Helv. Phys. Acta **26**, 433 (1953).

MONDAY MORNING AT 10:00

Physics 372

(PAUL KIRKPATRICK, presiding)

Contributed Papers

B1. Uniformity of Pulse Heights from a Large-Area Photomultiplier.* A. M. HUDSON AND F. X. ROSER,† *Department of Physics and W. W. Hansen Laboratories of Physics, Stanford University*.—Following a suggestion of R. Hofstadter, a specially designed light baffle has been constructed for use with a large-area photomultiplier (RCA type C7157). This baffle improves the uniformity of pulse heights for scintillation events originating at various regions near the photocathode.

One end of a 2-in.×4-in.×4-in. liquid scintillator cell was viewed by the 2-in.×4-in. photocathode surface. When Co^{60} γ rays were collimated through different parts of the cell, the pulse heights for events near the ends of the photocathode were 14 percent lower than those near the center of the photocathode. With the baffle, this variation is less than 3 percent. Similar measurements using a 5819, (a) in contact with the cell, and (b) 4 inches away with a hollow, smoked MgO cone as a "light pipe," result in an improvement from 20 percent to 4 percent. These improvements in uniformity are at the expense of a loss of between one-half and one-third of the light collected with corresponding decrease in resolution.

* The research reported in this document was supported jointly by the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
† Sponsored by the National Research Council of Brazil.

B2. Proton-Deuteron Scattering at 20 Mev.* DAVID O. CALDWELL,† J. REGINALD RICHARDSON, AND HERBERT N. ROYDEN, *Department of Physics, University of California.*—The absolute differential cross-section for the elastic scattering of 20.6-Mev protons from deuterons has been measured using the external proton beam of the University of California, Los Angeles synchrocyclotron. A triple-coincidence proportional counter telescope with variable absorbers between the second and third counters and differential pulse-height discriminators on all three counters was used to select the desired particle by range and specific ionization. Measurements have been made at 22 angles from 12° to 164° (all angles are center-of-mass). A few values of the center-of-mass differential cross-section (in millibarns/steradian), subject to considerable revision by corrections yet to be made, are: 15.0°, 72.8; 18.7°, 69.8; 22.5°, 73.9; 29.9°, 77.8; 51.7°, 52.2; 91.9°, 15.5; 130.0°, 2.7; 150.0°, 16.5; 160.0°, 32.9. This shows the familiar deep minimum, but in addition a shallower minimum near 20°, due to Coulomb-nuclear interference. Presumably, this latter minimum should allow the fitting of the data with a unique set of phase shifts. Heretofore such three-body scattering experiments have by themselves yielded two ambiguous sets of phase shifts, and consequently doublet and quartet scattering lengths.

* Assisted by the joint program of the U. S. Office of Naval Research and U. S. Atomic Energy Commission.
† This work was performed while under U. S. Atomic Energy Commission and National Science Foundation Fellowships. Now at Physikalisches Institut, E. T. H., Zurich, Switzerland.

B3. Radiations from Scandium-40, Chlorine-32, Phosphorus-28, and Aluminum-24.* NEEL W. GLASS AND J. REGINALD RICHARDSON, *Physics Department, University of California, Los Angeles.*—Scandium-40, a new positron emitter of the series $Z=2n+1$, $A=4n$ has been produced by the $Ca^{40}(p,n)Sc^{40}$ reaction using 20-Mev protons in the University of California, Los Angeles cyclotron. The half life is 0.22 ± 0.03 sec and the threshold 15.9 ± 1.0 Mev. A single γ ray of energy 3.75 ± 0.04 Mev and positrons of maximum energy 9.0 ± 0.4 Mev are present. Measurements on previously reported[1,2] members of the series, Cl^{32}, P^{28}, and Al^{24} yielded the following results: Four γ rays up to an energy of 4.77 ± 0.04 Mev and maximum positron energy of 9.4 ± 0.3 Mev for Cl^{32}; seven or possibly eight γ rays up to an energy of 7.59 ± 0.15 Mev and maximum positron energy of 10.6 ± 0.4 Mev for P^{28}; five γ rays up to an energy of 7.12 ± 0.10 Mev for Al^{24}. The reported[1] delayed heavy particles from Al^{24} have been determined to be alpha particles. Delayed alpha particles in the Cl^{32} decay have also been detected. Although energetically possible, no delayed heavy particles were detected in the P^{28} and Sc^{40} decays.

* Supported in part by joint program of U. S. Atomic Energy Commission and U. S. Office of Naval Research.
[1] A. C. Birge, Phys. Rev. 85, 753 (1952).
[2] Glass, Jensen, and Richardson, Phys. Rev. 90, 320 (1953).

B4. Specific Ionization of High-Energy Electrons in Hydrogen and Nitrogen.* W. C. BARBER, *Hansen Laboratories of Physics, Stanford University.*—The specific ionization of electrons has been measured for hydrogen and nitrogen over the energy range 13 to 31 Mev. The electrons were accelerated in the Stanford 35-Mev accelerator, magnetically analyzed to approximately one percent energy spread, and collimated into a beam of $\frac{1}{8}$-in.×$\frac{1}{2}$-in. cross section. This beam was passed through an ion chamber, whose sensitive length was $2\frac{1}{2}$ inches, then collected in a Faraday cup. Ion and electron currents were integrated simultaneously, the ratio of the collected charges being proportional to the specific ionization. The specific ionization of both gases showed a steady rise of 5 percent over the energy range 13 to 31 Mev. At 31 Mev the data corrected to N.T.P. gave 8.3 ion pairs per cm for hydrogen and 60 ion pairs per cm for nitrogen. Although individually measured points show a reproducibility of better than one percent, uncertainties in the response of the Faraday cup integrator make the absolute values and the rise with energy uncertain to 2 or 3 percent. Experiments to improve the integrator performance and to extend the measurements to higher and lower energies are in progress.

* The research reported in this document was supported jointly by the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

B5. Measurements of Reflection of 8-Angstrom X-Rays by Mirror Surfaces.* ROY W. HENDRICK, JR., *Stanford University.*—X-radiation for these measurements originated in a 2.5-kv x-ray tube whose target was an aluminum wire 0.01 inch in diameter, bombarded laterally at about 1 watt of power. After filtration by 0.001 inch of aluminum foil to emphasize the aluminum K lines, the radiation underwent reflection at a plane mirror surface and was absorbed in a detector consisting of a CeBr (Th activated) scintillator and an RCA 6199 photomultiplier tube. The photomultiplier was cooled to liquid-nitrogen temperature to reduce background noise. Reflection coefficients were measured as functions of the small, grazing angle of incidence for mirrors of glass, magnesium, aluminum, copper, silver, and gold. The metal mirrors were formed by condensation upon glass flats, the coating process taking place within the vacuum chamber which housed the whole ray path from source to detector. Graphs will be presented showing the decline of reflecting power to zero with increase of the grazing angle.

* Supported in part by a Grant-in-Aid from the American Cancer Society upon recommendation of the Committee on Growth of the National Research Council.

B6. X-Ray Microscope Mirror Systems.* A. V. BAEZ AND M. WEISSBLUTH, *Stanford University.*—Rays were traced through several x-ray microscope mirror systems with the aid of an IBM electronic computer. Simple mirror systems of circular and of elliptical profile were investigated as were also two compound systems each consisting of a combination of hyperbolic and elliptical mirrors. The circular mirror was combined with a stop placed so as to have maximum effect in rectifying the image. With angles of incidence limited to about 10 mr, an object distance of 2 cm, a magnification of 75 and an aperture angle of 1 mr, the results indicated a resolving distance at the object of about 4000A over a field of 30μ. Over this field the resolution and magnification vary by about 20 percent. An elliptical mirror, computed with comparable numerical assumptions, provides similar resolution but only over a field of about 5μ. The Gaussian image surface is very oblique and the use of an auxiliary aperture stop is less effective than for the sphere. The principal aberration of compound systems is field curvature, comatic effects being unimportant. With a magnification of 40, and aperture angle of 1 mr, it is possible in a four-mirror system to achieve a resolving distance of 1500A over a field of 20μ.

* Supported in part by a Grant-in-Aid from the American Cancer Society upon recommendation of the Committee on Growth of the National Research Council.

B7. Photosensitive Cell Response to Sinusoidally Varying Light Flux. R. L. CONGER AND L. E. SCHILBERG, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—The effect of sinusoidally modulated light produced by a light chopper on PbS cells has been measured. It was found that a curve of PbS cell signal attenuation as a function of chopping frequency based on the assumption of an exponential response for the PbS cell fit the experimental data quite well.

B8. Sodium Iodide Counting Response for Gamma Rays. W. E. KREGER AND L. MCISAAC, *U. S. Naval Radiological Defense Laboratory.*—The response of a sodium iodide crystal spectrometer to gamma rays of 0.279, 0.411, 0.662, 0.745, and 1.11 Mev has been measured using an automatic recording pulse-height analyzer. Five cylindrical NaI crystals were used having the following sizes: 1 cm×1 cm, 1 in.×1 in., 2 in.×2 in., 4 in.×4 in., $1\frac{1}{2}$ in.×1 in., and 2 in.×1 in. The effect of different sources distances and preparation on the response has been determined for the 0.662-Mev gamma ray. Spectrometer resolution has been determined as a function of crystal size and gamma-ray energy. The photoelectric yield has been compared to total counting response in order to determine relative efficiency of the crystals for different gamma-ray energies by photoelectric peak yield.

B9. Quantitative Measurement of Magnetic Absorption Utilizing a Null-Balance System. R. H. ELSKEN AND T. M. SHAW, *Western Regional Research Laboratory.**—Nuclear magnetic absorption spectroscopy is being used to investigate the sorption of water by hygroscopic solids.[1] To obtain improved precision for quantitative measurements, the r-f spectrometer employed has been designed to operate as a null-balance instrument. A calibrated modulated electronic resistance[2] serves as an artificial absorption. The artificial absorption signal is adjusted to oppose the nuclear resonance signal obtained under conditions of slow sweep operation, with modulation less than line width. Lack of balance between the nuclear absorption and the artificial absorption results in an error signal at the output of the phase detector of the conventional r-f spectrometer. The error signal is used to control a motor which varies the artificial absorption. Provision for recording is made by mechanically coupling the motor to the pen of a conventional strip-chart recorder. Tests show this type of spectrometer has several advantages over other systems primarily because of the reduction in the number of components of the spectrometer that require stabilization to achieve high precision.

* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.
[1] T. M. Shaw and R. H. Elsken, J. Chem. Phys. **21**, 565 (1953).
[2] G. D. Watkins and R. V. Pound, Phys. Rev. **82**, 343 (1951).

MONDAY AFTERNOON AT 2:00

Physics 370

(L. B. LOEB, presiding)

Division of Electron Physics

Invited Papers

C1. Correlation of Electronic Band Structure with Properties of Silicon and Germanium. CONYERS HERRING, *Bell Telephone Laboratories.* (40 min.)

C2. Recent Developments in Field Emission. JOSEPH E. HENDERSON, *University of Washington.* (40 min.)

C3. Microwave Studies of Electron Diffusion in Gases. SANBORN C. BROWN, *Massachusetts Institute of Technology.* (40 min.)

Contributed Papers

C4. Absorption Cross Sections for Photoionizing Radiations in Low-Pressure Gases.* C. D. MAUNSELL, *Department of Physics, University of California, Berkeley, California.*—Experiments have been carried out to obtain absorption coefficients of pure gases for photoionizing radiations produced in the same gas. The photon source region was a field free box into which an electron beam of 0–50-volt energy was sent. Photons could leave a hole in this box and after traversing the gas enter a Kingdon cage space-charge detector used to measure the number of positive ions produced. The distance between the photon source and Kingdon cage was varied to obtain absorption coefficients. Since the radiations of interest were in the vacuum ultraviolet, no windows could be used to separate the various regions of the apparatus so all parts were operated at the same low pressure (1–10 microns). The variation in Kingdon cage current caused by the photoionization was measured either in a dc bucking circuit or by using pulsed excitation and a synchronous amplifier. The dependence of photoionization on source voltage, source current and pressure has been studied for various gases.

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

C5. The Effect of Temperature on Field Emission.* W. W. DOLAN, W. P. DYKE, J. K. TROLAN, AND J. P. BARBOUR, *Physics Department, Linfield College.*—Both the current density and the distribution in energy of electrons emitted from metals are calculated for various combinations of temperature, applied surface electric field and work function. A wider range of those variables than previously achieved is made possible by use of numerical integration. The integrand is the usual function based on the free-electron theory of metals and the wave-mechanical barrier transmission coefficient of Sommerfeld and Bethe which assumes a classical image force and a plane surface. Results, which are presented in graphical form, are consistent with the Fowler-Nordheim field emission equation for low temperatures, and with the Richardson thermionic emission formula at low fields. Predicted emission at temperatures up to 3000°K is compared with cold emission at fields between 10^7 and 10^8 v/cm. The calculated current densities are confirmed experimentally for a work function of 4.5 ev, at fields from 2.6 to 6.8×10^7 v/cm, and temperatures up to 1400°K at the lower fields and up to 2000°K at the higher fields.

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

C6. Refined Electron Beam Probe Studies in Glow Discharges.* ROGER W. WARREN, *Department of Physics, University of California, Berkeley.*—The electric field in a glow discharge has been measured by probing high-energy electron beam. The probing beam crossing the discharge is acted on by two parallel but opposing forces; that due to the electric field, and that due to an externally applied magnetic field. The total deflection is detected by a fluorescent screen and two photomultipliers. The signal from the photomultipliers is used to automatically adjust the magnetic field so that net beam deflection is zero. The electric field is thus directly proportional to the compensating magnetic field, which is readily measured. Fields from less than one to greater than one thousand volts per centimeter have been measured. The electrodes of the discharge are moved with respect to the electron beam at a constant speed and a recorder is used to make a direct plot of field *versus* position over the whole discharge in minutes. The magnetic compensating field is so small relative to the electric fields that the discharge is little affected. Data to date covers air.

* This work was initially supported by the U. S. Office of Naval Research. The results reported were obtained under a National Science Foundation Grant.

C7. Current Growth in the Formative Time Lag of Sparks.* H. W. Bandel, *Department of Physics, University of California, Berkeley.*—Following the work of Fisher and associates,[1,2] an oscilloscopic study has been made of the growth of current preceding streamer spark breakdown during long formative time lags at low over-voltages. Time lags from 10–100 microseconds are being observed in dried air. Currents have been observed from microamperes in the early part of the formative time rising to 10^{-2} ampere just before breakdown. Data will be presented showing the variations in the current buildup caused by changes in the photoelectric i_0, gap length, and gas pressure.

* The project during development of the intricate instrumentation was supported by the U. S. Office of Naval Research and the Research Corporation of America. The collection of the present data was done with a National Science Foundation Grant.

[1] L. H. Fisher and B. Bederson, Phys. Rev. **81**, 109 (1951).
[2] G. A. Kachickas, Doctor's Thesis, New York University.

Tuesday Morning at 9:00

Cubberley Auditorium

(L. I. Schiff, presiding)

Symposium on Nuclear Magnetism

Invited Papers

D1. Recent Developments in Nuclear Induction. Felix Bloch, *Stanford University.* (40 min.)

D2. Nuclear Interactions in Molecules. N. F. Ramsey, *Harvard University.* (30 min.)

D3. Some Recent Results in Nuclear Magnetism. R. V. Pound, *Harvard University.* (30 min.)

D4. Free Nuclear Induction Experiments Involving Pure Nuclear Electric Quadrupole Interactions. Erwin Hahn, *Watson Scientific Computing Laboratory (IBM), Columbia University.* (30 min.)

D5. Quadrupole Splitting of Nuclear Magnetic Resonance Lines in Single Crystals. G. M. Volkoff, *University of British Columbia.* (30 min.)

Tuesday at 12:15

Stanford Union

(J. Kaplan, presiding)

Luncheon of the American Physical Society

Tuesday Afternoon at 2:00

Cubberley Auditorium

(Felix Bloch, presiding)

Symposium on Nuclear Magnetism

Invited Papers

E1. Paramagnetic Relaxation in Free Radical Solutions Exhibiting Hyperfine Structure. G. E. Pake, *Washington University.* (30 min.)

E2. Some Recent Measurements of Nuclear Moments. Carson Jeffries, *University of California, Berkeley.* (30 min.)

E3. Nuclear Magnetic Resonance Phenomena in Metals and Alloys. W. D. Knight, *University of California, Berkeley.* (30 min.)

E4. Nuclear Magnetism Study of Polymers. Eugene Guth, *University of Notre Dame.* (30 min.)

WEDNESDAY MORNING AT 9:00

Physics 372

(R. T. BIRGE, presiding)

Contributed Papers

F1. Measurements of Cyclotron Neutron and Gamma Fields for Animal Irradiation Studies. S. W. ROSS, E. TOCHILIN, AND B. W. SHUMWAY, *U. S. Naval Radiological Defense Laboratory.*—Physical Dosimetry measurements were made at the U. C. 60-in. cyclotron. Neutrons were produced by bombarding a thick Be target with 20-Mev deuterons. Fast neutron flux intensity and angular field distribution were measured with sulfur threshold detectors. In the forward direction, 30 in. from the cyclotron target, the flux was found to be 5×10^8 neutrons/cm^2/μamp-min. The half-width of the angle for half-maximum intensity was found to be 16°, which agrees with Schecter's observations.[1] An estimate of the relative neutron flux above the sulfur threshold was made using the neutron spectrum given by Cohen and Falk for 15-Mev deuterons on Be.[2] For 20-Mev deuterons this ratio will not change appreciably. On this basis 2×10^8 neutrons/cm^2 equal 1 rep. The associated thermal neutron flux, measured with gold foils, was sufficiently low to produce no appreciable ionization. Gamma radiation, measured by standard film techniques, constituted no more than 10 percent of the total rep dose. Investigations at NBS have indicated that 20 rep of 2-Mev neutrons produce film blackening equivalent to 1 *r* of Ra gamma rays.

[1] L. Schecter, Phys. Rev. **83**, 695 (1951).
[2] B. L. Cohen and C. E. Falk, Phys. Rev. **84**, 173 (1951).

F2. Limiting Range of Reynolds' Number in Determining Flow Permeability. H. L. MORRISON AND G. J. PLAIN, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—In determining flow permeability of porous media by some application of Darcy's law,[1] it is usually assumed essential that the flow velocity be kept low enough to keep the flow laminar. The flow permeability of 14 media composed of nearly spherical glass beads, randomly packed, has been ascertained after the method of Terzaghi.[1,2] Using three fluids (water and two Dow-Corning silicons) having viscosities of 0.00874, 0.0940, and 0.968 poise, respectively, it was found that for a Reynolds' number of 75 or less, there was excellent agreement in the measured permeabilities. The range of permeabilities in the 14 media was from 6×10^{-8} cm^2 to $39\,000\times10^{-8}$ cm^2.

[1] M. Muskat, *The Flow of Homogeneous Fluids through Porous Media* (J. W. Edwards, Inc., Ann Arbor, Michigan, 1946).
[2] D. P. Krynine, *Soil Mechanics* (McGraw-Hill Book Company, Inc., New York, 1941).

F3. On Some Numerical Regularities in the Periodic System of Ions. N. EFREMOV, *1061 Intervale Avenue, New York, New York.*—According to the proposed method of calculation of ionic radii* the magnitudes of ionic radii may be characterized by means of simple small numbers obtained from the new form of the periodic system of ions based on special matrix. These numbers may be considered as "compensators of valence." These compensators are directly proportional to the magnitude of the ionic radii. Quadruple groups of ions show a simple numerical regularity. The sum which is obtained from adding the compensator of valence and the valence of an ion is a constant number for the given quadruple group of ions arranged in the order of increasing atomic numbers, e.g.,

Ions	Na	Mg	Al	Si
Numbers of electrons:	10	10	10	10
Ionic radii in AE:	0.95(=5×0.19)	0.76(=4×0.19)	0.57(=3×0.19)	0.38(=2×0.19)
Compensator:	5	4	3	2
Valence:	1	2	3	4
Constant number:	6	6	6	6

In this way "compensator of valence" may be linked with valence in a straight line equation: $y=b-x$, where y = valence, x = compensator of valence, and b = simple constant number (4, 5, 6, etc). The "compensator of valence" notion is useful, as pairs of ions with equal or nearly equal compensators of valence (such as Li−Mg, Mg−Sc, Be−Al, B−Si, Na−Ca, etc.) are characterized by joint migration and mutual isomorphous substitution in crystalline lattices.

* Paper given at the September, 1953, meeting of the American Physical Society in Albuquerque, New Mexico.

F4. An Improved High-Intensity Short-Duration Light Source. FRANK N. MILLER, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—A high-intensity, short-duration, compact point light source is described. The gap was developed for use in photography and shadowgraphy of projectiles that travel several mm/μsec. The source is characterized by ample intensity over an effective time interval of 11×10^{-8} μsec.

F5. The Shock-Wave Valve. RICHARD I. CONDIT, *Broadview Research and Development.*—A convenient and versatile source of shock waves has been realized in the shock-wave valve. It allows the production of shock waves from the sudden release of compressed gas. The sudden release is accomplished by a series of quick-opening mechanical valves cascaded from the size appropriate to the output down to the size that is readily controlled by a solenoid. The assembly is self-contained and automatically recycling, so that shock waves can be repeatedly produced by merely activating the solenoid. (Operation requires no disassembly or replacement of frangible diaphragms.) Operating characteristics of a small model will presented. The device appears promising as a means for exciting shock tubes in the laboratory or in the field. In this application single units have been useful in producing simple plane shock fronts, while multiple units would seem to be useful in producing shock fronts of considerable complexity exhibiting multiple peaks and valleys and other pressure-time relations of practical interest. A new degree of control of experimental sources of shock waves may thus be allowed by shock-wave valves.

F6. Thermal Microstructure in the Ocean. W. N. ENGLISH, *Pacific Naval Laboratory, Esquimalt, British Columbia, Canada.*—The thermistor equipment previously described[1] has been used in conjunction with a tape recorder and a Kay Electric Company "Vibralyser" to obtain a one-dimensional Fourier analysis of some temperature structures in the Esquimalt approaches. A tape speed of eleven inches per hour is used for recording, and a speed of $7\frac{1}{2}$ or 15 inches per second for playback to the Vibralyser. The "spectra" obtained show good agreement with paper records and are also being checked by a photographic process. Representative spectra will be presented and discussed.

[1] W. N. English, Phys. Rev. **92**, 1087(A) (1953).

F7. Response Currents in Coupled Circuits by the Laplace Transformation and a Mechanical Harmonic Synthesizer. CHU JUI LEE AND S. LEROY BROWN, *University of Texas.*—For a linear system of networks having constant lumped elements, the determination of the response current in any mesh of network involves the solution of a set of simultaneous linear constant-coefficient integrodifferential equations in one independent variable with driving functions having bounded variations in every finite interval and with general initial or boundary conditions. Cases of special interest are electrical circuits to which electromotive forces of periodic nature are applied. Since linear equations possess additive properties, the law of superposition can be applied, and from a system of linear equations it is possible to add the separate solutions found by using each driving function alone and get the composite solution for all driving functions present. The complete solution of a system of these integrodifferential equations can be obtained through one of four methods—the classical method, the Heaviside operational method, the Fourier transformation method, or the Laplace transformation method. If Laplace transformation is used, a mechanical harmonic synthesizer may be used to determine the roots of polynomial equations to facilitate the Heaviside partial fraction expansion in the process of solving the inverse transforms. Solutions of specific problems illustrate the use that may be made of a harmonic synthesizer.

F8. Asymptotic Spherical Shock Decay. L. M. TANNENWALD, *U. S. Naval Ordnance Test Station.*—Quasi-stationary approximations are used to solve the equations of motion of a weak, expanding spherical shock wave propagating through a viscous and heat-conductive medium far from the origin of the initial disturbance. An ordinary first-order differential equation is obtained which describes the shock strength attenuation as a function of distance from the center of the spherical wave. An approximate solution of the above-mentioned differential equation is also given.

F9. A Jet-Tone Orifice Number for Orifices of Small Thickness-Diameter Ratio. A. B. C. ANDERSON, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—The dependence of a jet-tone orifice number $tf/(\Delta p/\rho)^{\frac{1}{2}}$ on Reynolds number $[\rho t(\Delta p/\rho/\mu)^{\frac{1}{2}}]$ is shown for thin sharp-edged circular orifices whose thickness and diameter both vary from approximately $\frac{1}{8}$ to $\frac{3}{8}$ in., where t is thickness of orifice plate, f frequency, Δp pressure difference across orifice, ρ density, and μ viscosity of gas. Each jet-tone, in general, is composed of harmonics (fundamental and overtones) as well as subharmonics (tones whose frequencies are less than the fundamental). The subharmonics are relatively unsteady in amplitude compared to the harmonics, and may, at times, have a greater amplitude. The jet tones at low Reynolds numbers appear relatively free of noise background. In general, as Reynolds number is increased to high values, the noise background at first engulfs the subharmonics, then the harmonics. The fundamental is the last to remain, finally disappearing in the noise background.

F10. Fast Jet Actuated Shock Tubes.* F. J. WILLIG, *University of California, Los Alamos Scientific Laboratory.*—A small glass shock tube partitioned at its center by means of a thin diaphragm is actuated by directing a fast jet[1] into one end. In traversing the distance to the partition, a high pressure is generated which in turn imparts a high shock velocity to the region beyond. The entire process is highly self-luminous, hence may be recorded by means of a moving image slit camera operating at high speed. Hydrogen gas at a pressure of about one-third of an atmosphere is used in the first part of the tube while the pressure in the other part is maintained at a much lower value. If the latter region is highly evacuated, velocities in the neighborhood of 10^7 cm/sec may be obtained.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Koski, Lucy, Shreffler, and Willig, J. Appl. Phys. **23**, 1300 (1952).

F11. New Observations of Hydrocarbon Flame Growth.* R. K. SHERBURNE AND J. S. ARNOLD,† *Physical Science Laboratory, New Mexico College of Agriculture and Mechanic Arts.*—Minimum ignition energies of hydrocarbon air mixtures in terms of a measured "critical radius" have been discussed previously.[1] Using the same experimental method the studies have been extended from the original mixtures, methane, ethane, butane, and propane with air, to include isobutane (altered molecular form), ethylene (double bond), acetylene (triple bond) and ratios of oxygen to nitrogen other than the 21/79 value for air. Earlier work[1] showed that ignition occurs most readily for mixtures in which the number of hydrogen atoms is equal to the number of oxygen. This criterion is found to hold for isobutane and variations in the oxygen to nitrogen ratio but fails for ethylene and acetylene mixtures.

* Supported by U. S. Office of Ordnance Research.
† Now at Stanford Research Institute, Menle Park, California.
[1] J. S. Arnold, and R. K. Sherburne, *Fourth Symposium (International) on Combustion* (Williams and Wilkins, Baltimore, Maryland, 1953), p. 139.

F12. Atmospheric Disturbances and Stellar Scintillations. F. ZWICKY, *California Institute of Technology.*—Perturbations in the clear atmosphere can be analyzed through observations of stellar scintillations. Size, location, and velocity of vortices are obtained from drifted spectra and extrafocal images of stars. Density changes within vortices are determined from extrafocal images using various color filters. The instantaneous mass per cm^2 column in direction of a star follows from the instantaneous location of lines in the drifted spectrum. Shock waves, oscillations, as well as vortices subtending large angles, cause related changes in the drifted spectra of many stars as they appear in the field of a wide angle telescope. Through the use of two telescopes the element of triangulation is introduced with corresponding gain in accuracy of lengths measured. Among the many applications which can be made of the above-mentioned methods, observations on the internal seeing in the solar and planetary atmospheres appear most suggestive. The author intends to make such observations during the total eclipse of the sun in 1954 for the purpose of exploring perturbations in the sun's atmosphere and for further clarification of the nature of the gravitational deflection of light rays.

F13. Shift and Broadening of the Blue Cs Doublet Produced by Argon and Helium.* SHANG-YI CH'EN AND WILLIAM J. PARKER, *Department of Physics, University of Oregon.*—The shift and broadening of the 2nd member of the principal series of caesium produced by argon and helium were observed for pressures up to 170 and 90 atmospheres, respectively. The shift produced by argon was linear throughout the entire range of relative densities and was nearly the same for both doublet components. The average slope was 2.7 cm^{-1}/r.d. with the short wavelength component ($^2P_{\frac{3}{2}}$) having a slightly higher value. For helium the shift obeyed a linear relationship for relative densities above 8 and 16 with slopes of 3.5 and 4.4 cm^{-1}/r.d. for the $^2P_{\frac{1}{2}}$ and the $^2P_{\frac{3}{2}}$ components, respectively. The broadening for both lines in the case of argon appeared to be linear up to a relative density of 45 beyond which there was a marked increase in slope, changing from 2.0 to 5.1 cm^{-1}/r.d. The broadening of the $^2P_{\frac{3}{2}}$ component was consistently higher than that of the $^2P_{\frac{1}{2}}$ component. For helium the $^2P_{\frac{1}{2}}$ component was broadened more than the $^2P_{\frac{3}{2}}$ component at relative densities less than 12.5. Beyond this value the broadening of the $^2P_{\frac{3}{2}}$ component was considerably higher. With helium for densities greater than 32.4, the lines overlapped too much to allow a reliable determination of the half-widths, although the shifts were measured up to a relative density of 44. These results are in general agreement with previous observations for rubidium.[1]

* Supported by the National Science Foundation.
[1] S. Y. Ch'en and D. A. Kohler, Phys. Rev. **90**, 1019 (1953).

F14. The OPW Method for Calculating Energy Eigenvalues Extended to Crystals of Compounds.* TRUMAN O. WOODRUFF, *California Institute of Technology and Hughes Research and Development Laboratories.*—Recent theoretical work by Herman[1] on the energy band structure of diamond-type valence crystals and experimental studies in various laboratories of the properties of crystals of semiconducting materials with the zincblende-type structure[2] have led the author to undertake calculations of important details of the energy band structure of some semiconducting zincblende-type crystals. In connection with this work, Herring's orthogonalized plane wave (OPW) method[3] for calculating energy eigenvalues in a crystal has been extended to cases in which the unit cell of the crystal contains s atoms all of different kinds. Expressions for the matrix elements entering into such calculations will be presented.

* This work was carried out while the author was a Member of the Technical Staff of the Hughes Research and Development Laboratories and while a holder of a Howard Hughes Fellowship.
[1] F. Herman, Phys. Rev. **88**, 1210 (1952); Ph.D. Thesis, Columbia University, January, 1953.
[2] H. Welker, Z. Naturforsch. **7a**, 744 (1952); Breckenridge, Hosler, and Oshinsky, Phys. Rev. **91**, 243 (1953); Willardson, Beer, and Middleton, Phys. Rev.**91**, 243 (1953); M. Tanenbaum and G. L. Pearson, Phys. Rev. **91**, 244 (1953).
[3] C. Herring, Phys. Rev. **57**, 1169 (1940).

WEDNESDAY MORNING AT 9:00

Physics 370

(W. K. H. PANOFSKY, presiding)

Contributed Papers

G1. Photospallation Yields of N^{17}.* DARYL REAGAN, *W. W. Hansen Laboratories of Physics and Department of Physics, Stanford University.*†—The yields of N^{17} [1] arising from the 180-Mev x-ray bombardment of several low Z elements have been measured. Preliminary results for the integrated cross sections for the following reactions are: $O^{18}(\gamma,p)N^{17}$, 0.5-Mev barn; $F^{19}(\gamma,2p)N^{17}$, 0.02-Mev barn; $Na^{23}(\gamma,\alpha,2p)N^{17}$, 2×10^{-3} Mev barn; $Mg^{24}(\gamma,\alpha,3p)N^{17}$, 5×10^{-4} Mev barn; $Al^{27}(\gamma,2\alpha,2p)N^{17}$, 3×10^{-4} Mev barn; $Si^{28}(\gamma,2\alpha,3p)N^{17}$, 3×10^{-5} Mev barn; $P^{31}(\gamma,3\alpha,2p)N^{17}$, 3×10^{-4} Mev barn; $S^{32}(\gamma,3\alpha,3p)N^{17}$, $<10^{-4}$ Mev barn; $Cl^{35}(\gamma,4\alpha,2p)N^{17}$, and $Cl^{37}(\gamma,5\alpha)N^{17}$, $<10^{-4}$ Mev barn.

* The research reported in this document was supported jointly by the U. S. Navy (Office of Naval Research) and the U. S. Atomic Energy Commission.
† Introduced by W. K. H. Panofsky, Stanford University.
[1] Knable, Lawrence, Leith, Moyer, and Thornton, Phys. Rev. **74**, 1217 (1948).

G2. Classical Theory of Heavy Nuclei I.* E. TELLER AND M. H. JOHNSON, *University of California, Berkeley.*—The nuclear shell model indicates the existence of a smooth average potential within nuclei. This potential might be generated by a smooth and nearly spherical pion wave function. In heavy nuclei the positive, negative, and neutral wave functions will be occupied by several π mesons so that the field will be classical. As a consequence of isotopic spin invariance, a potential proportional to the meson wave function does not give effective nuclear binding. Therefore more complicated interactions must be explored. The pseudoscalar nature of the meson suggests that the main interaction with the meson field occurs by emission and absorption of meson pairs, thereby making the potential depend on the square of the meson wave function. Spin-orbit coupling would be due to an additional pseudovector term which depends linearly on the meson wave function. In the classical description it is necessary to distinguish between six fields representing positive, negative, and neutral mesons present in even and odd numbers.

* Work supported by the U. S. Atomic Energy Commission.

G3. Classical Theory of Heavy Nuclei II.* M. H. JOHNSON AND E. TELLER, *University of California, Berkeley.*—Definite eigenvalue equations governing the meson (ϕ) and nucleon (ψ) wave functions follow from minimizing the energy in which nucleons are treated as a degenerate gas. A constant density approximation indicates that equilibrium for the correct nuclear radii, with correct nuclear binding and proper meson scattering properties, can be achieved by the interaction $\psi^2 a\phi^2(1+b\phi^2)^{-1}$ for $b\phi^2\sim3$ and $a\phi^2\sim-160$ Mev. Numerical integration of the equations for different radii gives the appropriate surface energy. However, if separate neutron and proton fields are introduced, the energy minimum occurs for too small proton densities. An additional term in the interaction proportional to the nucleon kinetic energy raises the proton densities. It is equivalent to decreasing the nucleon's effective mass. As the meson field is intimately related to the nucleon's self-energy, an external meson field may well change the nucleon's effective mass. Moreover, the change necessary to obtain a correct neutron-proton ratio reduces the potential scattering of heavy nuclei to zero at 150 Mev in agreement with experiment.[1]

* Work supported by the U. S. Atomic Energy Commission.
[1] S. Fernbach, UCRL Report 1382, July 1951.

G4. Cosmic-Ray Transition Phenomena Due to Electrons, Photons, and Mesons.* ROBERT B. BRODE, *University of California, Berkeley.*—With a suitable arrangement of over a hundred Geiger counters, it has been possible to study in some detail the characteristics of the transition as the cosmic radiation passes from air to denser matter. Narrow pairs of electrons initiated by electrons and by photons showed a maximum in their transition at about one radiation length of matter. Showers showed a maximum of the Rossi type at about three radiation lengths of matter. No evidence was found for a second maximum in the transition curves produced by incident photons, electrons, and mesons. The dependence on atomic number and radiation length of material of the transition curves for the knock-on electrons due to mesons is qualitatively in agreement with theoretical predictions.

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

G5. Comments on Fermi's Theory of the Origin of Cosmic Rays. LEVERETT DAVIS, JR., *California Institute of Technology.*—Fermi's[1] collisions between cosmic-ray particles and moving pieces of the galactic magnetic field **B** reverse the component along **B** of the particles momentum and, on the average, slightly increase its magnitude. The normal component is unchanged. With chaotic **B** very high-energy particles result; but with the roughly uniform **B** that now seems more probable, energy increases by a large factor are not easily built up. Therefore, introduce type C or betatron collisions in which a particle spiraling around a field line passes through a region where $\mathbf{B}$ is changing in time. Space variations do not matter. This produces random changes in energy of the same magnitude as did Fermi's collisions, if the observed interstellar gas velocity is ascribed to vibrations in **B**. Even without positive second-order terms, random walk analysis gives the observed energy spectrum. The increased momentum normal to **B** enables Fermi's collisions to increase the parallel component. Random walk analysis applied to Fermi's collisions shows that statistical fluctuations are about as important as the positive second-order term.

[1] E. Fermi, Phys. Rev. **75**, 1169 (1949).

G6. Isotope Displacement in λ4415A Cd II. ERVIN C. WOODWARD, JR.,* *Department of Physics, University of California, Berkeley.*—Using mixtures of separated isotopes of cadmium in a modified Schüler hollow cathode discharge tube with a Fabry-Perot etalon in conjunction with a large prism spectrograph, the transition

$$\text{Cd II}\,(4d^{10}5p\,{}^2P_{\frac{3}{2}}-4d^{9}5S^2\,{}^2D_{\frac{5}{2}})$$

at λ4415A was investigated for the isotope displacement of the isotopes Cd^{111} and Cd^{113} since earlier work of Schüler and Westmeyer,[1] and Brix and Steudel[2] gave meager and inconclusive data for these two isotopes. The centers of gravity of both the Cd^{111} and Cd^{113} hyperfine structure patterns were found to lie between the Cd^{110} and the Cd^{112} levels. The shift between Cd^{111} and Cd^{113} is 39.7×10^{-3} cm^{-1}. This is some 26 percent less than the displacement between either Cd^{110} and Cd^{112} and Cd^{112} and Cd^{114}. Though only a relative shift was measured, the difference is in such a sense as to possibly indicate an abnormally large nuclear radius for Cd^{111}.

* Now at Radiation Laboratory, University of California, Livermore, California.
[1] H. Schüler and H. Westmeyer, Z. Physik **82**, 685 (1933).
[2] P. Brix and A. Steudel, Z. Physik **128**, 260 (1950).

G7. Triplet Production in Hydrogen at 300 Mev by a Total Absorption Method. J. D. ANDERSON, C. A. MCDONALD, JR., AND R. F. POST, *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—The attenuation of 300-Mev photons in liquid hydrocarbons has been measured and used to infer the cross section for triplet production (pairs produced in the field of an electron). Targets of benzene (C_6H_6) and cyclohexane (C_6H_{12}) were used in good geometry; attenuation was measured by substitution of a dummy target. A pair spectrometer with fast counter channels was used. The beam was monitored by a 300-Mev monitor.[1] The total attenuation cross sections in hydrogen and carbon found are: $\sigma_H=(1.95\pm0.2)\times10^{-26}$ cm^2 and $\sigma_C=(31.8\pm0.3)\times10^{-26}$ cm^2 (statistical errors—about 10^6 total counts). At 300 Mev three processes dominate: (1) Compton effect,[2] (2) ordinary pair-production, and (3) triplet production, $\sigma_T(\text{theoretical})=7.96\times10^{-27}$ cm^2.[3] Subtraction of (1) and (2) from σ_H yields $\sigma_T(\text{H})=(8.4\pm2.0)\times10^{-27}$ cm^2, in agreement with theory. In σ_H photonuclear processes are negligible by comparison. σ_T can also be calculated from σ_C, giving $\sigma_T(\text{carbon})=(8.0\pm0.5)\times10^{-27}$ cm^2, in agreement with $\sigma_T(\text{H})$. Although the statistical error in $\sigma_T(\text{carbon})$ is smaller than that in $\sigma_T(\text{H})$, it is believed that $\sigma_T(\text{H})$ is more reliable because of uncertainties in shielding and other corrections necessary in calculating $\sigma_T(\text{carbon})$.

[1] McDonald, Kenney, and Post, Paper No. H14, this meeting.
[2] Kenney, Dudley, and McDonald, Paper No. H13, this meeting, gives an experimental verification of the theoretical value.
[3] J. Wheeler and W. Lamb, Phys. Rev. **55**, 858 (1939).

G8. Compton Effect at 250 Mev. F. H. COENSGEN. *Radiation Laboratory, Department of Physics, University of California, Berkeley, California.*—The electron Compton effect has been investigated using photons of the bremsstrahlung beam from the Berkeley synchrotron. Photons in a 27-Mev energy band about a mean energy of 250 Mev were selected by selecting recoil electrons in a given momentum interval and measuring the angle through which the photons were scattered. It is estimated that the primary energy band is known within three percent. Cesium fluoride crystals were used to detect photons and phenylcyclohexane activated with 4 g/liter of terphenyl was used in all other detectors. A Compton event is identified as a coincidence between a pulse from a photon detector and a pulse from an electron detector. The amplitude and length of the pulses from the photomultipliers are limited but not amplified before reaching a germanium diode coincidence circuit. A resolving time of 2×10^{-8} second was used. Precautions against contamination by pair production were taken. Counting rates have been measured to approximately 10 percent for photon scatter angles of 4, 8, 16, 20, and 25 degrees. Cross sections computed from these measurements agree within the limits of the experiment with those computed from the differential Klein-Nishina formula.

G9. Relative Low-Energy Pion Production Cross Sections by Photons on Hydrogen. RYOKICHI SAGANE AND WALTER F. DUDZIAK. *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—A successful method of shielding a synchrotron from an external strong horizontal magnetic field has been found. As a result it is now possible to use a magnet as a spiral orbit spectrometer near a synchrotron for the study of numerous problems where the counting rate is very small. In particular the study of relative pion production cross sections at 90 degrees to the gamma-ray beam in the low-energy region ($T_\pi>4$ Mev) where the spectrometer is most efficient, becomes greatly simplified. A test experiment was made using a maximum gamma-ray energy of 300 Mev for the problem of pion production from hydrogen. A carbon-polyethylene subtraction technique was used. The created pions were detected by C-2 200μ nuclear emulsions positioned in the stable orbit. The preliminary results from this test experiment at pion energies of ($T_\pi=10$, 20, 35, 45, 55) will be presented.

G10. Dependence of Relative Low-Energy $\pi^\pm$ Production Cross Section on Atomic and Neutron Numbers. WALTER F. DUDZIAK AND RYOKICHI SAGANE. *Radiation Laboratory, Department of Physics, University of California, Berkeley, California.*—Preliminary data[1-3] at three pion energies ($T_\pi=12.5$, 27, and 35 Mev) have been obtained on the relative yield of charged pions from the interaction of 340-Mev protons with complex nuclei. For the experiment a 22-in. spiral orbit spectrometer was used. As a result production cross sections at 90 degrees to the proton beam from Be, C, Al, Cu, Ag, Ta, Pb, and U were obtained. The charged mesons were detected by means of C-2 200μ nuclear emulsions located at the stable orbit A comparison of the plots for the positive pions clearly reveals that the variation with atomic number is not the same at the three energies. A deviation occurs from the $T_\pi=35$-Mev data as the pion energy is lowered. The direction of this deviation is the same as would be expected from the effect of the nuclear Coulomb field. However, there is reason to believe that the nuclear Coulomb field may not suffice to explain this deviation. A comparison of negative pion production when plotted against neutron number does not reveal an appreciable opposite effect.

[1] R. Sagane and W. Dudziak, Phys. Rev. **92**, 212 (1953).
[2] W. Dudziak and R. Sagane, UCRL-2304.
[3] R. Sagane and W. Dudziak, UCRL-2317.

G11. Phase Shift Calculation of High-Energy Electron Scattering by Nuclei. I.* D. R. YENNIE, R. N. WILSON, AND D. G. RAVENHALL, *Stanford University.*—In this paper we shall describe the computational program for calculating the elastic scattering of electrons from spherically symmetrical charge distributions, and in the following paper the results will be presented and compared with experiment. The calculation follows in general the methods given by Parzen[1] and Acheson,[2] with some modifications in the details. To calculate the phase shifts, the radial wave functions inside the nucleus are integrated numerically and fitted to Coulomb functions (obtained by series expansion about the origin) outside the nucleus. In order to obtain relatively accurate differential cross sections for large angles ($>90°$), it is necessary that the phase shift errors be kept small (less than 10^{-4} radian) In this angular region it is also necessary to know the Coulomb scattering amplitude very accurately. A new method of summing the series for this amplitude will be given.

* Supported by the U. S. Office of Scientific Research, Air Research and Development Command.
[1] G. Parzen, Phys. Rev. **80**, 355 (1953).
[2] L. K. Acheson, Jr., Phys. Rev. **82**, 488 (1951).

G12. Phase Shift Calculation of High-Energy Electron Scattering by Nuclei. II.*,[1] D. G. Ravenhall, D. R. Yennie, and R. N. Wilson, *Stanford University*.—For gold, $Z=79$, we have calculated differential cross sections for uniform, exponential and intermediate charge distributions. Compared with the first Born approximation, the maxima and minima given by the uniform charge distributions are smoothed out, the first minimum appearing only as a point of inflection. The slope of the cross section for the exponential distribution is greater than that given by the first Born approximation; this effect can be understood qualitatively as being due to the increase of the electron's wave number inside the attractive potential of the nucleus. For comparison, some distributions for copper ($Z=29$) have also been obtained. The maxima and minima are more pronounced and are shifted to smaller angles relative to the Born approximation, an effect explainable qualitatively in terms of the effective wave number. Further calculations now in progress will be reported and compared with the experimental results of Hofstadter, Fechter, and McIntyre.[2]

* Supported by the U. S. Office of Scientific Research, Air Research and Development Command.
[1] Some of these results have been reported in a Letter to the Editor of *The Physical Review*.
[2] Hofstadter, Fechter, and McIntyre, Phys. Rev. **91**, 422 (1953); **92**, 978 (1953).

G13. Second Born Approximation to the Scattering of Fast Electrons and Positrons by Nuclei.* R. N. Wilson, *Stanford University*.—The scattering of a Dirac particle in an electrostatic potential is calculated in second Born approximation. A charge distribution of the form

$$\rho(r)=(Ze/8\pi a^3)\exp(-r/a)$$

is chosen because the integrations can be performed exactly and because it is of interest to compare the result with an exact calculation by phase shift analysis, as reported in the preceding two papers. In the imaginary part of the second-order contribution to the scattering amplitude there appear divergent terms which are to be interpreted as phase corrections to the first-order contribution.[1] A comparison is made of the results of this calculation with the first Born approximation and with the exact phase shift calculation.

* Supported by the U. S. Office of Scientific Research, Air Research and Development Command.
[1] R. H. Dalitz, Proc. Roy. Soc. (London) **206**, 514 (1951).

G14. Achromatic Translation System for High-Energy Beams.* Wolfgang K. H. Panofsky, *W. W. Hansen Laboratories of Physics and Department of Physics, Stanford University*.—The beam of electronuclear machines frequently requires magnetic analysis in order to provide a beam of known energy and energy width, free from secondary particles. A system has been designed which achieves this aim without destroying the geometrical character of the beam. The system achieves a parallel translation of the beam, the amount of the translation being independent of energy to the first order. The system consists of a deflecting magnet followed by three quadrupole lenses, followed by a second deflecting magnet which bends the beam into a path parallel to the initial beam. Construction details will be given.

* The research reported in this document was supported jointly by the U. S. Navy (Office of Naval Research) and the U. S. Atomic Energy Commission.

Wednesday Afternoon at 2:00

Physics 370

(R. Hofstadter, presiding)

Contributed Papers

H1. On the Decay of Cl^{33}. W. E. Meyerhof, *Stanford University*, and G. Lindstrom, *Nobel Institute of Physics, Stockholm*.*—In the decay of Cl^{33} (half-life $\sim$2.5 sec) a gamma ray of energy 2.9 Mev has been found with a branching ratio of $\sim\frac{1}{3}$ percent. The log-ft for the positron branch leading to the 2.9-Mev state of S^{33} is 4.0 ± 0.3, indicating even parity for this state (assuming that the ground state of Cl^{33} has even parity). This result is in agreement with $S^{32}(n,\gamma)$ data,[1] but does not agree with interpretation of $S^{32}(d,p)$[2] and $S^{32}(d,n)$[3] scattering experiments leading to the 2.9-Mev state of S^{33} and the corresponding state in Cl^{33}.

* Work performed at Stanford University.
[1] Kinsey, Bartholomew, and Walker, Phys. Rev. **85**, 1012 (1952).
[2] J. R. Holt and T. N. Marsham, Proc. Phys. Soc. (London) **A66**, 467 (1953).
[3] Middleton, El-Bedewi, and Tai, Proc. Phys. Soc. (London) **66**, 95 (1953).

H2. Photoproduction of Neutral Pions at High Energies.* D. C. Oakley, R. L. Walker, J. G. Teasdale, and J. I. Vette, *California Institute of Technology*.—Measurements of the excitation function for photoproduction of neutral pions in hydrogen at photon energies between 250 and 470 Mev have been continued with the Cal-Tech synchrotron by a different method than previously reported.[1] The magnetic spectrometer used for the π^+ photoproduction cross section[2] has been used to count the recoil protons from the photoproduction of π^0's in a high-pressure, liquid nitrogen cooled hydrogen target, assuming these protons are due only to the π^0 photoproduction. Measurements have been made at $12\frac{1}{2}°$ and 32° for the proton in the lab system at energies corresponding to incident photons from 250 to 470 Mev. These results are in approximate agreement with those obtained previously by counting both a proton and one of the π^0 decay γ rays.[1]

* This work was supported by the U. S. Atomic Energy Commission.
[1] Walker, Oakley, and Tollestrup, Phys. Rev. **89**, 1301 (1953).
[2] Walker, Teasdale, and Peterson, Phys. Rev. **92**, 1090(A), (1953).

H3. Photofission Produced by 335-Mev Bremsstrahlung. J. Jungerman, *University of California at Davis*, and H. Steiner, *University of California, Berkeley*.—We have determined the photofission cross section for several substances at the maximum energy of the Berkeley synchrotron. A cancellation technique was employed in a hydrogen-filled ionization chamber that gives a 2π geometry for the fission fragments and a background from the beam ionization of less than one percent. The number of equivalent quanta were determined by using replicas of the thermally calibrated Cornell and Illinois ionization chambers, and the maximum energy of the spread-out beam was found to be 335 Mev using a pair spectrometer. The fission cross section per equivalent quantum is found to be 225 mb, 160 mb, 43.5 mb, and 2.52 mb for U^{235}, U^{238}, Th^{232}, and Bi^{209}, respectively. The counting statistical error is two percent or better in all cases.

H4. Interpretation of Experiments on Nuclear Temperatures.* DAVID BREED BEARD, *University of California at Davis and the University of Connecticut Inelastic Neutron Scattering Project.*—The expression for particle emission spectra common to many theories of heavy nuclei, $E\exp 2\{a(E_m-E)\}^{\frac{1}{2}}$, has been approximated by Weisskopf to const $E\exp\{-E/T\}$, where $T=(E_m/a)^{\frac{1}{2}}$, E is the emitted particle energy, E_m is the excitation energy of the compound nucleus above its ground state, and a is constant. Hurwitz and Bethe have remarked that capture cross section data indicate the energy of the excited nucleus should be measured, not from the ground state, but from a characteristic level which is a smooth function of atomic mass. Additional and rather strong evidence comes from: (1) plots of experimentally observed nuclear temperatures, T, *vs* atomic mass for equal excitation energies in which temperature is observed to remain constant or even increase with atomic mass. (This indicates E_m increases with atomic mass at least as fast as a, as would follow from a decrease in binding energy per nucleon with increasing mass number.) And (2) observations of how nuclear temperature depends on excitation energy, in which nuclear temperature is found to increase faster with excitation energy that $(E_m)^{\frac{1}{2}}$ if E_m is measured from the ground state. Characteristic levels have been estimated.

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

H5. Velocity of Spread of Burst Pulses in Air with Coaxial Cylindrical Geometry.* ELSA L. HUBER, *Department of Physics, University of California, Berkeley.*—Bursts pulses in room air at a pressure of 300 mm in a coaxial cylindrical system have been investigated with a high-speed synchroscope. The velocity of spread along the central positive wire has been determined using two collimated α-particle beams for triggering the pulses, one directed parallel to the wire, and the other perpendicular to it. In the former case, the primary ionization occurs essentially instantaneously along the entire length of the wire, while in the latter it is initially confined to a single point on the wire, with the subsequent spread depending on photoionization of the gas. The observed difference in rise time of the two types of pulses yields the time and hence velocity of the spreading process. By diluting the air with nitrogen, but maintaining a constant pressure, this velocity has been found to vary with the partial pressure of oxygen.

* This work was initially supported by the U. S. Office of Naval Research but the data here reported were obtained under a grant from the National Science Foundation.

H6. A Monitor for High-Energy Electron or γ-Ray Beams.* A. V. TOLLESTRUP AND W. A. WENTZEL, *California Institute of Technology.*—A monitor for use with high-energy γ-ray beam of the Cal-Tech synchrotron has been developed which has some advantages not possessed by the conventional ionization chamber. First, it may be gated easily, and secondly, its response is very fast and is not limited as is an ionization chamber by ion-collection time. Unfortunately, it is not an absolute device and hence it must be calibrated. The monitor consists of a one-meter long gas-filled metal tube with a thin aluminum window at the front and rear for the beam to pass through. Electrons made in a thin converter in front of the apparatus emit Čerenkov radiation in the gas which is reflected onto the cathode of a 5819 photomultiplier by a thin aluminized Lucite mirror set at 45° to the beam direction. The 5819 which is located one meter away from the beam axis and is shielded with 2 in. of lead is gated by a pulse applied to its last two dynodes and its output goes to a standard current integrator. βn must be greater than 1 for Čerenkov radiation to be emitted and this corresponds to a low-energy cutoff of 20 Mev for air at STP and to 60 Mev for helium at STP and is inversely proportional to the square root of the pressure. Turning the monitor end-for-end shows the light produced by ionization is negligible. Leakage and dark current constitute a small background.

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

H7. A 500-Mev Pair Spectrometer.* DUANE H. COOPER, DAVID C. OAKLEY, AND ROBERT L. WALKER, *California Institute of Technology.*—A pair spectrometer has been built for measuring the photon spectrum and some absorption coefficients in the Bremsstrahlung beam from the Cal-Tech synchrotron. The 50-kw 35-ton magnet can produce 15 000 gauss in a 4-inch gap over a 40-inch equilateral triangular area. This places 550-Mev photons in the central energy channel. The detectors are 10 plastic scintillators on each side of a 60° V inside the gap, each coupled through a Lucite light pipe to its photomultiplier on top of the magnet. Instead of having a separate coincidence circuit for every possible pairing of detectors across the V, we use a time-delay multiplexing scheme, suggested by Matthew Sands. This reduces the number of amplifiers from 20 to only 4, which need feed only as many coincidence channels as there are energy channels. The use of distributed amplifiers readily permits a coincidence resolving time of 10 millimicroseconds.

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

H8. Lifetime Measurements for the First Excited States of O^{117} and B^{10} from Recoil Studies.* JACQUES THIRION AND VALENTINE L. TELEGDI,† *Kellogg Radiation Laboratory, California Institute of Technology.*—The measurement of the distance traversed by an excited recoil nucleus before deexcitation can be used for determining lifetimes of the order of 10^{-11} sec or longer.[1] We have applied this method to the γ rays emitted by the first excited states of O^{17} (870 kev) and B^{10} (720 kev).[2] These states were excited by deuteron-induced reactions on O^{16} and Be^{9}. A collimated deuteron beam ($\frac{1}{8}$ in. diameter) strikes a thin target mounted on Ni backing (0.6 mg/cm^2) and the recoils are ejected into vacuum. The γ rays are detected by means of a NaI spectrometer (10 channels) of 8 percent resolution for the 870-kev photopeak. The crystal sees the region accessible to the recoils through a tungsten collimator. Mechanical displacement of the target with respect to the collimator enables one to vary the distance of flight of the recoils seen by the detector. The following lifetimes have been obtained: O^{17} 870-kev level $(2.5\pm1)10^{-10}$ sec; B^{10} 720-kev level $(7\pm2)10^{-10}$ sec.

* Assisted by the joint program of the U. S. Office of Naval Research and U. S. Atomic Energy Commission.
† Visiting Research Fellow from the Institute for Nuclear Studies, University of Chicago.
[1] J. C. Jacobsen, Phil. Mag. **47**, 23 (1924); Devons, Hereward, and Lindsay, Nature **164**, 586 (1949).
[2] R. G. Thomas and T. Lauritsen, Phys. Rev. **88**, 969 (1952).

H9. Gamma-Radiation from $C^{13}+D^2$.† R. J. MACKIN, JR., W. B. MIMS,* AND W. R. MILLS, *Kellogg Radiation Laboratory, California Institute of Technology.*—A magnetic lens spectrometer was used to investigate the gamma radiation above 3.5 Mev produced by the deuteron bombardment of C^{13}-enriched soot. A study of the Compton electron spectra from a thin converter (20 mg/cm² C plus 21 mg/cm² Al) at $E_d=1.42$ Mev revealed the following gamma lines (energies in kev, not corrected for possible Doppler shift): 4930±40, 5130±30, 5730±30, 6119±25. A weak line at 3910±50 kev was established with the spectrum from a 125 mg/cm² Al converter. At $E_d=1.9$ Mev, additional lines appeared at 6450±50 and 6730±40 kev. No new lines were discovered at $E_d=2.6$ Mev. The well-known 6.12-Mev line is from C^{14},† as is probably the 6.73-Mev line. All other lines correspond to known levels of N^{14}. A predicted line at 5.82 Mev[1] was not observed; its intensity at $E_d=1.42$ Mev is less than 0.15 that of the 5.73-Mev line.

† Assisted by the joint program of the U. S. Office of Naval Research and U. S. Atomic Energy Commission.
* Commonwealth Fund Fellow, now at the Clarendon Laboratory, Oxford, England.
[1] Woodbury, Day, and Tollestrup, Phys. Rev. 92, 1199 (1953).

H10. Inelastic Scattering of Protons by F^{19}.† R. W. Peterson, C. A. Barnes, W. A. Fowler, and C. C. Lauritsen, *Kellogg Radiation Laboratory, California Institute of Technology*.—Two previously unreported groups of inelastically scattered protons have been found, corresponding to the two low-lying levels of F^{19} reported by Mileikowsky and Wahling.[1] Measurements of the energies of these two groups at 100° and 159° in the lab system at several bombarding energies yields values of 108±2 kev and 200±3 kev for the excitation energies of these two levels. The excitation curve for the protons to the first-excited state shows the well-known 1.355- and 1.381-Mev resonances, and in addition a much stronger resonance at 1.419 Mev. The elastic scattering of protons from this level in Ne^{20} indicates that it is 1^+. The γ rays from these two levels to the ground state and from the 200-kev level to the 108-kev level have been observed. Further work on the proton groups and the associated γ rays is in progress.

† Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] C. Mileikowsky and W. Whaling, Phys. Rev. 88, 1254 (1952).

H11. Neutron Total Cross Section for Bismuth and Uranium Between 45 and 130 Mev. W. I. Linlor and B. Ragent, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—Neutron total cross sections for bismuth and uranium have been measured in a good geometry transmission experiment, using a time-of-flight instrumentation.[1,2] Uncertainties shown are standard deviations based on counting statistics only and on energy channel width.

Neutron		Bismuth		Uranium	
Energy (Mev)	Error (Mev)	σ (Barns)	$d\sigma$ (Barns)	σ (Barns)	$d\sigma$ (Barns)
45	4	4.74	0.18	4.96	0.21
53	3	4.50	0.18	4.44	0.21
62	4	4.14	0.14	4.53	0.17
70	3	4.92	0.12	5.30	0.15
78	4	4.74	0.10	5.13	0.12
89	5	4.71	0.09	5.10	0.11
100	6	4.54	0.09	5.00	0.11
113	7	4.22	0.11	4.67	0.13
131	8	3.63	0.17	4.29	0.21

[1] University of California Radiation Laboratory Report.
[2] W. I. Linlor and B. Ragent, Phys. Rev. 91, 440 (1953).

H12. Total Neutron Cross Sections for Carbon, Iron, Antimony, and Tantalum from 35 to 180 Mev. B. Ragent and W. I. Linlor, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—The total neutron cross sections for carbon, iron, antimony, and tantalum have been measured in the region of 35 to 180 Mev in a good geometry absorption experiment using time-of-flight instrumentation developed for the 184-inch cyclotron. Tantalum exhibits a shallow dip in the cross section curve in the region of 50 to 70 Mev. It is apparent within the statistics that antimony has a dip at about the same energies, and that iron and carbon have a relatively flat region at these energies.

H13. Absolute Photon Attenuation Cross Section for Non-Pair Processes in Beryllium at 300 Mev. Robert W. Kenney, John M. Dudley, and Charles A. McDonald, Jr., *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—The total cross section for the attenuation of 300-Mev photons by nonpair forming processes in beryllium has been found to be $0.0148\pm0.0011\cdot10^{-24}$ cm²/Be atom. This result is 18 percent higher than the theoretical total Compton cross section in beryllium at 300 Mev. A discussion of photon interactions with nuclei will be given, their cross sections in beryllium at 300 Mev will be estimated, and their theoretical dependences on Z and energy included. The nonpair, non-Compton processes contribute at least 10 percent of the measured cross section. From the tentative data, one can conclude thst the Klein-Nishina formula is correct to within 6 percent at 300 Mev. Final results will be presented. The total absorption cross sections at 300 Mev in beryllium and lead have been found to be $0.1599\pm0.0007\cdot10^{-24}$ cm²/Be atom and $37.57\pm0.07\cdot10^{-24}$ cm²/Pb atom, respectively. The ratio of the pair forming cross section at 300 Mev in beryllium to that in lead has been found to be $3.90\pm0.01\cdot10^{-3}$.

H14. A Monitor for High-Energy Photons. C. A. McDonald, Jr., R. W. Kenney, and R. F. Post, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—It has been common practice to use ionization chambers for monitoring the bremsstrahlung beams of high-energy electron accelerators. An ionization chamber was found to be inadequate for monitoring the 330-Mev spectrum of the Berkeley synchrotron when a single channel pair spectrometer was used at energies above 300 Mev. The contribution of a small-energy interval, in a bremsstrahlung spectrum, to the over-all response of an ionization chamber becomes small as the mean energy of that interval approaches the quantum limit of the spectrum. An ionization chamber is therefore a poor monitor for bremsstrahlung flux in an energy interval near the quantum limit, particularly if the quantum limit fluctuates. An adequate magnetic-type monitor will be described, in which electrons from a thin lead converter are analyzed by a magnetic field. Only 300±15-Mev electrons are accepted by a narrow momentum channel and detected by a 2-in. diameter sodium iodide crystal. The crystal is viewed by a 5819 photomultiplier, the output of which is integrated on a condenser and recorded by an electrometer circuit. The instantaneous photomultiplier current is 3 orders of magnitude smaller than rated maximum current. It will be shown that the magnetic-type monitor tracks the pair spectrometer better than an ionization chamber. The monitor discriminates very sharply against low-energy background.

Wednesday Afternoon at 2:00

Physics 372

(J. Kaplan, presiding)

Contributed Papers

I1. Ionization by Ultra-Speed Pellets.* C. D. Hendricks, Jr., M. E. Van Valkenburg, W. G. Clay, and R. A. Davidson, *University of Utah*.—Ultra-speed pellets have been produced having velocities from 2 to 10 km/sec using techniques developed by Rinehart, White, and Allan at Inyokern. The ionization produced as the pellets pass through the air has been studied by means of microwave reflections and by measuring charge with high potential plates. Preliminary measurements show that at least 10^{12} electrons per cm of path are created by pellets in the velocity range studied. Visual flares have been observed in all ultra-speed pellets fired thus far.

* This research was supported by the U. S. Office of Ordnance Research.

I2. A Slotted Resonant Cavity for Dielectric Measurements. J. J. Windle and T. M. Shaw, *Western Regional Research Laboratory*.*—Cavities operating in the TM_{010} mode at 3030 and 9300 Mc have been constructed with a narrow slot cut parallel to the direction of current flow in the walls. The slot, which can be considered as a perturbation[1] of the cavity boundaries, has only a small effect on the resonant frequency and Q. The applications of such cavities to the determination of the dielectric properties of wool fibers is being investigated[2]. In one application two slotted cavities are used. One cavity contains the test specimen, the other (reference cavity) contains a composite dielectric and an H-field tuner which are calibrated and provide independent controls of the resonant frequency and Q, so that the response curve of the reference cavity can be matched to that of the cavity containing the test specimen. In a study of the effect of radiation on the dielectric properties of materials, the slot can serve as a window through which the specimen can be irradiated over its entire length, yet the high Q necessary for sensitivity can be maintained.

* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.
[1] J. C. Slater, Revs. Modern Phys. **18**, 441 (1946).
[2] T. M. Shaw and J. J. Windle, J. Appl. Phys. **21**, 956 (1950).

I3. Kinetics of Ordering in AuCu Alloys.* G. C. Kuczynski and R. Hochman, *University of Notre Dame*.—Gold copper alloys corresponding to almost the exact composition AuCu were disordered at 415°, 440°, and 650°C for twenty hours. Subsequently, the samples were water quenched and ordered isothermally at various temperatures below 400°C. Electrical resistivity measurements and x-ray and metallographic examination revealed the following: (1) The faster the ordering process, the higher was the disordering temperature. The samples disordered at lower temperatures (415°, 440°C) exhibited long induction periods when ordered at temperatures close to 400°C. (2) It has been found that there are two temperature zones defined by two sharply different mechanisms of transformation. *Zone A* extends from 360° to 405°C. The ordering in this zone is a function of nucleation only and its rate increases with decreasing temperature. The resulting structure contains plates of an ordered phase readily observable under a microscope. These plates form and propogate in an extremely short time (a fraction of a second). *Zone B* contains all temperatures below 375°C. The rate of ordering in this zone decreases with decreasing ordering temperatures. An analysis of the electrical resistivity *versus* time curves reveals that this phase also is nucleated but its growth is slow.

* Work supported by the U. S. Army Office of Ordnance Research and the Union Carbon and Carbide Company.

I4. Thermal Conductivity of Graphite. Alan W. Smith, *North American Aviation, Inc., Atomic Energy Research Department*.—The thermal conductivity of a number of types of graphite has been measured over the range 10°K to 300°K. The measurements were made by passing current through a sample and measuring the resulting parabolic temperature profile. The results substantiate those of Berman,[1] and Tyler and Wilson.[2] The thermal conductivity varies as $T^{2.7}$ in some samples at low temperatures while the specific heat varies as T^2. An increase in conductivity with increased crystallite size is observed. However, it is to be emphasized that, due to uncertain orientation and density corrections as well as the anomalous temperature dependence of the conductivity, determinations of crystallite size from thermal conductivity are apt to be entirely erroneous. The effect of anisotropy of the graphite lattice is shown to alter the relationship between the thermal conductivity and the specific heat only by a geometric factor. The anomalous thermal conductivity can possibly be explained by an isotropic intergranular region if 5 to 10 percent of the total carbon is in this region. The effect of scattering by electrons is discussed and the use of brom-graphite compounds to study this effect proposed.

[1] R. Berman, Proc. Phys. Soc. (London) **A65**, 1029 (1952).
[2] W. W. Tyler and A. C. Wilson, Jr., Phys. Rev. **89**, 870 (1953).

I5. Cyclotron Resonance in Germanium Crystals. A. F. Kip, G. Dresselhaus, and C. Kittel, *Department of Physics, University of California, Berkeley*.—Cyclotron resonance has been observed[1] in n- and p-type germanium crystals near 4°K near 9000 Mc and 24 000 Mc. The conduction electrons or holes are curved in spiral orbits by the application of a static magnetic field. The angular frequency of the orbits is given by $\omega = eH/m^*c$, where m^* is the effective mass of the carrier. Resonance absorption of energy occurs when the applied frequency is equal to the frequency of the orbits. In n-Ge the effective mass is $m^*/m = 0.1$; in p-Ge two resonances are observed, corresponding to $m^*/m = 0.04$ and 0.3. The effective mass found for n-Ge accounts approximately for the anomalous infrared absorption reported by Fan and Becker.[2] The cyclotron resonances have been observed under conditions of both thermal ionization and rf induced carrier multiplication.

[1] Dresselhaus, Kip, and Kittel, Phys. Rev. **92**, 827 (1953).
[2] *Semiconducting Materials* (Butterworths Scientific Publications, London, 1951).

I6. Electron-Spin Resonance Absorption in Bulk and Dispersed Lithium and Sodium. G. Feher and T. W. Griswold,* *Department of Physics, University of California, Berkeley*.—Electron spin resonance has been observed in plates of lithium and sodium thick in comparison with a skin depth. According to unpublished calculations by Dyson, the absorption line shape is expected to depend on the ratio T_D/T_2, where T_D is the time associated with diffusion of conduction electrons out of the skin depth, and T_2 is the spin relaxation time. The line shape was observed to vary as expected with the ratio T_D/T_2, which varies with temperature and frequency. This effect demonstrates unequivocably that the resonance is caused by conduction electrons. The g values, as determined by direct comparison with a free radical, are: Li, 2.002 ± 0.001; Na, 2.001 ± 0.001. When the particle size is less than the skin depth, the line width is a direct measure of the intrinsic relaxation time. The intrinsic width between absorption inflection points is, at room temperature and 300 Mc, approximately 5 oersteds in lithium and 10 oersteds in sodium. With decreasing temperature the width increases in lithium and decreases in sodium.

* Now at Hughes Aircraft Company.

I7. Pure Rotational Spectra of the Alkali Halides. A. Honig,* M. Mandel, M. L. Stitch,† and C. H. Townes, *Columbia University*.—The pure rotational spectra of most of the alkali halides have been observed using a high-temperature microwave spectrometer[1] operating at temperatures up to 900°C. Internuclear distances, vibration-rotation interactions, and mass ratios of the stable isotopes of the alkali and halogen nuclei have been determined with great accuracy. In several of the lighter molecules, electric quadrupole coupling constants and electric dipole moments have been measured. In the cases of LiBr and LiI, it has been found possible to estimate the amount of ionic character of the bond by comparing the mass ratio of the Li^6 and Li^7 isotopes determined by nuclear reaction methods with the mass ratio determined from the rotational constants in this present work. The discrepancy indicates the proportion of time the Li valence electron spends at the halogen. Figures of 77 ± 35 percent, and 75 ± 35 percent ionic character have been obtained for LiBr and LiI, respectively. It has also been possible to determine the first four coefficients in the Dunham[2] expansion of the potential, $V[(r-r_e)/r_e]$, for many of the molecules investigated, provided information concerning the vibrational spectra is available.

* Now with the Department of Physics, University of California, Berkeley, California.
† Now with Varian Associates, Palo Alto, California.
[1] Stitch, Honig, and Townes, Phys. Rev. **86**, 813 (1952).
[2] J. L. Dunham, Phys. Rev. **41**, 721 (1932).

I8. Formation Energy of Vacancies in Copper. C. J. Meechan and R. R. Eggleston, *Atomic Energy Research Department, North American Aviation, Inc.*—The electrical resistance of a pure copper wire has been measured as a function of temperature from 0°C to 950°C. The experimental data between 160°C and 500°C were fitted by the empirical expression $R=R_0(1+\alpha T+\beta T^2)$, which gave an adequate fit within the experimental error up to 600°C. Above 600°C, the resistance values exceed the extrapolated curve by an amount ΔR which has the following temperature dependence: $\Delta R=A\exp(-E/kT)$. Because of the Boltzman temperature dependence, this excess resistance is attributed to the presence of vacant lattice sites existing in thermal equilibrium at the high temperatures. By plotting $\ln\Delta R$ *vs* $(1/T)$, a formation energy for vacancies in copper of 0.90 ± 0.05 ev was obtained. This paper is based on studies made for the U. S. Atomic Energy Commission.

I9. The Specific Heat of the Alloy $FeNi_3$ and of a Sigma Phase FeCr. David S. Bloom, *Michelson Laboratory, U. S. Naval Ordnance Test Station*.—The specific heat of a sigma-phase alloy FeCr and of the alloy $FeNi_3$, which is considered to undergo an order-disorder reaction, has been measured in the range from 0 to 1000°C. Some unexpected complications were observed.

I10. Measurements of the Rittenger's Number for Glass and Decomposed Granite. M. E. Backman and H. L. Morrison, *Michelson Laboratory, U. S. Naval Ordnance Test Station*.—An important parameter in the study of the breaking of brittle materials is Rittenger's number,[1] the ratio of the increase in area to the energy put into the crushed sample. Measurements have been made of Rittenger's number for glass and decomposed granite. A Gross and Zimmerley[2] type impact crusher was used for the measurement of the breaking energy. Measurements of the new surface were by permeabilities after the method of Terzaghi.[3] Three-mm glass beads were crushed to give a value of 10.5 sq cm/kg cm$\pm$4 percent. Sifted decomposed granite of two sizes was used. The first size passed a No. 5 sieve and was retained on No. 8 and the other passed through the No. 8 and was retained on a No. 14 sieve. Both of these sizes gave the same Rittenger's number, 33.6 sq cm/kg cm$\pm$3 percent.

[1] P. R. von Rittenger, *Lehrbuch der Aufbereitungskunde* (Berlin, 1867).
[2] J. Gross and S. R. Zimmerley, Am. Inst. Mining Met. Engrs. Tech. Pub. No. 126 (1928).
[3] M. Muskat, *The Flow of Fluids through Porous Media* (J. W. Edwards. Inc., Ann Arbor, Michigan, 1946).

I11. Aging of Evaporated Silver Films. W. F. Koehler, *Michelson Laboratory, U. S. Naval Ordnance Test Station*.—Precise measurements of the reflectance and the change in phase upon reflection as a function of wavelength and age will be presented to reveal some interesting aging effects of evaporated silver films.

I12. Coloring and Bleaching of Alkali Halide Crystals Containing *U* Centers. R. S. Alger, *U. S. Naval Radiological Defense Laboratory*.—Additional evidence regarding the role of traps in gamma-ray coloring and optical bleaching has been obtained by comparing crystals with and without *U* centers. Measurements of energy storage efficiency and *F*-center equilibrium concentration support the hypothesis that colorability is largely controlled by the type and availability of electron traps. Storage efficiency varies with temperature, increases with vacancy or *U*-center concentration and trap depth while equilibrium concentration increases with exposure rate. Under *F*-band illumination the *F* centers in both plane and *U*-centered crystals exhibit an initial period of rapid bleaching followed by a long slow bleaching period indicating that all *F* centers do not bleach with equal ease. Interrupting the bleaching of *U*-centered crystals by storage in the dark reinstates the higher bleaching rate. The slow rate is strongly temperature dependent, and varies slightly with light intensity or *U*-center concentration. If an *F*-center electron combines with a hydrogen atom and a vacancy in the *F*- to *U*-center reaction, the reaction rate appears to depend on the availability of hydrogen in the vicinity of vacancies. Favorably located hydrogens would be depleted during the initial rapid bleaching period while the slow bleaching depends on the speed with which hydrogens and vacancies reach favorable locations.

I13. Influence of Deuteron Bombardment and Strain Hardening on Mild Steel. Robert A. Meyer, *U. S. Naval Radiological Defense Laboratory*.—Schnadt-type impact specimens of mild steel were irradiated with 18.6-Mev deuterons from the purpose of studying the influence of radiation on the brittle property as measured by the change in transition temperature. The effect was compared with that of two, five, and ten percent strain hardening. Micro-hardness studies were made to determine the extent and location of the radiation effect. An integrated flux of 29.5 microampere-hr per cm^2 shifted the transition temperature from -1°C to 18°C. The embrittling action was not a linear function of dose. Hardness was increased from 180 to 264 Knoop numbers. It was found to depend on the depth of penetration as well as the integrated flux. While radiation caused an effect similar to strain hardening, the nature of this effect was different. Annealing studies showed recovery of the irradiated material occurred between 260°C and 480°C. An interstitial vacancy diffusion process was indicated. Activation energies increased as recovery progressed. Recovery of the five percent strain hardened material occurred between 316°C and 372°C and would appear to be grain boundary relaxation.

SUPPLEMENTARY PROGRAMME

SP1. Nuclear Spins of Mo^{95} and Mo^{97}.* ERVIN C. WOODWARD, JR.,† *Department of Physics, University of California, Berkeley.*—Because of the inconclusiveness of previous data[1,2] on the nuclear spins of Mo^{95} and Mo^{97}, especially separated isotopes of these two mass numbers‡ were employed in a modified Schüler hollow-cathode discharge tube with a Fabry-Perot etalon in conjunction with a large prison spectrograph, to obtain hyperfine structure patterns of spectral lines representing the transitions MoI ($4d^55s\ ^5S_2-4d^55p\ ^5P_{123}$) and MoI ($4d^45s^2\ ^5Do-4d^55p\ ^5P_1$). The appearance of the respective patterns of the two isotopes was very similar. The hyperfine structure of the $4d^55s\ ^5S_2$ state is normal, indicating in this case that both isotopes possess negative nuclear magnetic moments. Comparison of the observed hyperfine structure patterns with calculated patterns shows that the nuclear spin of both isotopes are 5/2. The nuclear spin value of 5/2 together with a negative magnetic moment for these two isotopes is in agreement with predicted values based on the shell model of the nucleus. The ratio of the nuclear magnetic moments of Mo^{97} to that of Mo^{95} is 1.022, in good agreement with the ratio obtained using nuclear induction techniques.[3]

* To be called for at the end of Session H if the Chairman rules that time permits.
† Now at Radiation Laboratory, University of California, Livermore, California.
[1] N. S. Grace and K. R. More, Phys. Rev. **45**, 166 (1935).
[2] O. H. Arroe, Phys. Rev. **79**, 212 (1950).
‡ Especially separated isotopes kindly supplied by Isotope Research and Production Division, Y-12 Research Laboratories of the Union Carbide and Carbon Corporation, Oak Ridge, Tennessee.
[3] W. G. Proctor and F. C. Yu, Phys. Rev. **81**, 20 (1951).

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