Proceedings of the American Physical Society

MINUTES OF THE MEETING AT LOS ANGELES, CALIFORNIA, JANUARY 3–4, 1947

THE 276th meeting of the American Physical Society was held on Friday and Saturday, January third and fourth, 1947, at Los Angeles in Harris Hall of the University of Southern California. This was our first meeting at that University, which furnished excellent accommodations and management for our sessions. Our thanks are due particularly to R. E. Vollrath and G. L. Weissler. The attendance at the most populous session amounted to some 200. The four invited papers were admirable in content and presentation. The vice president of the Society was prevented by the grounding of his plane from presiding at the session of invited papers, and was replaced as Chairman by C. S. Van Atta. The other Chairmen were R. E. Vollrath and J. Kaplan.

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Invited Papers

Interferometry. W. E. WILLIAMS, *Pasadena.*
Design of a Small Nuclear Reactor. ROBERT CHRISTY, *California Institute of Technology.*
Recent Progress in Applied Absorption Spectroscopy. R. R. BRATTAIN, *Shell Development Company.*
Recent Progress in Applied Mass Spectrometry. D. P. STEVENSON, *Shell Development Company.*

Contributed Papers

A1. The Atmospheric Bands of Oxygen. JOSEPH KAPLAN, *University of California, Los Angeles.*—A remarkable new afterglow has been discovered in which the well-known atmospheric bands of O_2 are emitted. This is the first time that these bands have been observed in emission. The bands of the system which were most readily photographed are the 0,0 band at λ7594 and the 0,1 band at approximately λ8650. The latter band has not been previously reported in either absorption or emission. Using small dispersion and Eastman IN plates, it was possible to obtain a good picture of the 7594 band in a one-hour exposure of the afterglow. Several other bands of the system and several apparently new bands of oxygen were obtained by using longer exposures. The new bands have not yet been identified. The exposure times were short compared with those needed to obtain comparable spectra of the auroral afterglow in nitrogen. The source of this new afterglow was a tube in which the auroral afterglow in nitrogen had been excited, and in which most of the nitrogen had been cleaned up. The addition of oxygen yielded this new glow. Considerable further study of this glow is planned because of its probable importance for the understanding of excitation processes in the upper atmosphere.

A2. Spectrophotometric Study of Reflectance Color Changes in Foods. E. J. EASTMOND, *Western Regional Research Laboratory.*—The influence of reflectance color on acceptability of foods has led to an investigation of the applicability of spectrophotometric methods to objective studies of color changes caused by processing conditions. Measurements have been made on a Hardy recording spectrophotometer and on a Hunter multipurpose reflectometer. Various methods of sample preparation have been investigated and the precision of results compared. Measurements can be made on samples in the original form, but in many cases homogenization is necessary for precision. In certain dehydrated foods chromaticity has been found to be essentially constant over fairly wide ranges of particle size and moisture content even though the brightness may vary considerably. In other cases careful standardization of particle size would be necessary to measure small color differences. Attention has been given to tristimulus specification and the precision of determination of trichromatic coefficients. These coefficients are useful as indices of reflectance color changes with time, temperature, and storage conditions. Luminous reflectance has also been found useful as a color variable. Changes in color are being correlated with quality and acceptability of food products.

A3. Possibility of Altering the Decay Rate of a Radioactive Substance. EMILIO SEGRÈ, *University of California, Berkeley.*—The radioactive decay constant of a substance decaying by orbital electron capture is proportional to $|\psi(0)|^2$ of the electrons. In the case of a light element like Be^7 it may be possible to alter this quantity by an appreciable amount by putting the Be in different chemical compounds. We would then have a slight change of the radioactive half-life of the Be in different compounds. The magnitude of the effect may be in the neighborhood of one percent, but it is practically impossible to give a quantita-

tive estimate because the total change of $\psi(0)$ is affected by certain factors such as the density of the crystal, nature of the chemical bond, etc. They are both positive and negative, and have comparable magnitudes. To obtain a reliable estimate of the effect we require a more detailed knowledge of the wave functions for various compounds than is at present available. Experiments are in progress to detect the effect by comparing the half-life of Be^7 in Be metal with that in BeO or BeF_2.

A4. Angular Distribution of α-Particles from Li^7+p. R. F. CHRISTY AND S. RUBIN, *California Institute of Technology.*—One of us has measured the angular distribution of α-particles resulting from the bombardment of a thin target of Li by protons of from 0.4 to 1.4 Mev. The same experiments gave some information on the variation of the total cross section for the reaction in the same energy range. The angular distribution is well represented by $1+A(E)\cos^2\theta$. A increases with energy up to 0.9 Mev where it has a maximum value of 2.1 and then decreases slightly to a value of 1.8 at 1.4 Mev. An attempt has been made to understand in terms of the dispersion theory the angular distribution in conjunction with the magnitude and energy dependence of the total cross section. Although the cross section above 0.4 Mev is not well known, it seems to show no pronounced indication of resonance from 0 to 1.4 Mev. A reasonable fit of the data is obtained with two resonances with $\Gamma\approx 1$ Mev at 0 and 1.8 Mev roughly. The latter is taken to have $J=2$ but the former may be $J=0$ or $J=2$. The proton width agrees well with that derived from the γ-ray resonance at 0.44 Mev only if the 0 energy resonance has also $J=2$.

A5. Angular Distribution of Long-Range Alpha-Particles from Excited Ne^{20}. SYLVAN RUBIN, *California Institute of Technology.*—Some preliminary measurements have been made of the angular distribution of the 5.9-cm alpha-particles from the reaction: $F^{19}(p,\alpha)O^{16}$. Measurements were made with a thin BeF_2 target at proton energies of 1.14, 1.20, 1.33 Mev, corresponding to the two highest resonance peaks and the minimum between them on the excitation curve.[1] The angular distribution was measured from 25° to 155° to the proton beam. The distributions were markedly asymmetric, with much stronger yield backward than forward. Previous measurements near 400 kev[2] showed strong asymmetry also, but with greater yield forward. Fitting of trial analytical angular distribution functions showed all powers of $\cos\theta$, at least up to $\cos^4\theta$, are needed to fit the data. The $\cos^3\theta$ and $\cos^4\theta$ terms indicate an appreciable effect from d-wave incident protons. A large $\cos^3\theta$ term at 1.14 Mev, and large $\cos\theta$ terms at 1.20 and 1.33 Mev, indicate strong interference among adjacent long range alpha-emitting states of Ne^{20}.

[1] J. F. Streib, W. A. Fowler, and C. C. Lauritsen, Phys. Rev. **59**, 253 (1941).
[2] W. B. McLean, A. Ellet, and J. A. Jacobs, Phys. Rev. **58**, 500 (1940).

A6. Device for Introducing Short-lived Radioactive Samples into a Cloud Chamber. T. LAURITSEN, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.*—In connection with the study of the radioactive products of Li^8 (0.88 sec.) a mechanism has been developed for automatically moving the activated target from the bombarding tube (at high vacuum) into the cloud chamber on a repeated cycle. The target is mounted at the end of a $\frac{5}{16}$" stainless steel rod which, with an interlocking extension rod, passes through a series of locks connecting the bombardment position and the cloud chamber. Immediately after bombardment of the target, an air cylinder advances the rod, pushing the target into a socket in the end of the extension rod and passing the assembly successively through a rough vacuum region, a region at cloud chamber pressure, and into the cloud chamber. Once the target is in the cloud chamber, a second air cylinder retracts the extension rod, exposing the target. The reverse motion consists in covering the target, passing through the locks and uncovering in the bombardment position. Seals between the pressure locks are provided by Koroseal sleeves lubricated with high vacuum oil. A slight rotation of the rod facilitates passage through the seals. The elapsed time for a 10" motion of the target into the chamber is about 1.5 sec. A somewhat longer interval is allowed on the return stroke to permit pumping out in the rough vacuum lock. This work was carried on under contract with the Office of Naval Research.

A7. Auger Showers. M. M. MILLS AND R. F. CHRISTY, *California Institute of Technology.*—Under the current assumptions of proton primaries in cosmic rays, the Auger showers (previously explained by primary electrons) demand a secondary source of energetic electrons or photons. A fast decaying mesotron ($\tau\sim 10^{-9}$ sec.) has already been proposed to account for the bulk of the soft component and β-decay lifetimes. The object of the present calculation is to determine whether this mesotron is also sufficient to account for Auger showers and bursts in unshielded ionization chambers. The coincident burst data of Lewis, which disagreed violently with the primary electron hypothesis,[1] has been examined in a preliminary way. If this experiment is to be explained at all in terms of ionization due to electrons, it will probably require initiating electrons of energy $>10^{14}$ ev produced predominately near the top of the atmosphere and with several electrons having considerable angular spread associated in one event. In terms of decay this would mean $\tau\leq 10^{-12}$ sec. An alternative possibility that the bursts are due to nuclear disintegrations is being examined. An experiment with three colinear chambers is suggested. The center would not necessarily fire simultaneously with the extremes according to these possibilities.

[1] L. Wolfenstein, Phys. Rev. **67**, 238 (1945).

A8. The Interpretation of the East-West Effect. ROBERT A. MILLIKAN, *California Institute of Technology.*—T. H. Johnson's equatorial measurements of the East-West effect indicate that the East-West dissymmetry is less at very high altitudes than at sea level. Suggestions are herewith presented which would limit the unbalance between positives and negatives to a region relatively near the earth in comparison with its radius and thus avoid the assumption of any electrical unbalance throughout space. Such an un-

balance has been generally recognized for fifty years as a valid objection to any theory which requires the earth to be bombarded by high speed particles of one sign only rather than of both signs, or else of no sign. If the validity of the principle is accepted all interpretation of the East-West effect must in some way or other conform with this principle of electrical balance throughout interstellar space. The suggestions necessary to produce such conformity are here discussed.

A9. Cosmic Ray Directional Counter for the Determination of the Azimuthal Variation of Primary Cosmic Radiation at Fixed Zenith Angles. ALFREDO BAÑOS, JR. AND M. L. PERUSQUÍA, *University of California, Los Angeles, and National University of Mexico, Mexico City.*—At the 1939 Symposium on Cosmic Rays held at the University of Chicago, M. S. Vallarta[1] suggested that the knowledge of the azimuthal variation of cosmic radiation could be used for the purpose of determining the sign and the energy spectrum of primary cosmic rays. In following this suggestion the writers designed, constructed, and operated, at the Institute of Physics of the National University of Mexico, an instrument consisting of four triple coincidence Geiger-Müller telescopes mounted at zenith angles of 0°, 20°, 40°, and 60°, and so arranged that, by rotation around a vertical axis, the directional intensity or counting rate could be measured at 16 equally spaced azimuths. The rotation and photographic recording were made fully automatic. Several novel features of the apparatus are here discussed. Most important of all is the feature that, in contradistinction to the usual parallel connection of the three counters, as used in the standard Rossi[2] circuit and necessitating an amplifier tube for each Geiger-Müller counter, a decided simplification in the circuits and a corresponding ease of operation were obtained by connecting the three counters in series feeding a single stage of amplification. Extensive statistical tests of the counting rate observed with the series connection were made by one of us[3] showing that the series connection was at least as reliable as the conventional parallel circuit. The results of two experiments, covering in excess of 100-days for each continuous run, have been reported by M. S. Vallarta.[4]

[1] M. S. Vallarta, Rev. Mod. Phys. 11, 239 (1939).
[2] B. Rossi, Nature 125, 636 (1930).
[3] Alfredo Baños, Jr., Rev. Mex. de Ing. y Arq. 19, 121–147 (1941).
[4] M. S. Vallarta, M. L. Perusquía and J. de Oyarzábal, Bull. Am. Phys. Soc. 21, Cl (September, 1946).

A10. On the Meson Theory of Nuclear Forces. LESLIE L. FOLDY, *Department of Physics and Radiation Laboratory, University of California, Berkeley, California.*—The failure of the Møller-Rosenfeld-Schwinger mixture to yield quantitative agreement with the observed properties of the deuteron has suggested the possibility that this agreement might be obtained with other mixtures in which tensor-force singularities are cancelled. Several such possibilities exist involving vector, pseudovector, and pseudoscalar mesons, some of which possess the interesting characteristic that they yield a finite tensor and central interaction in the limit where the meson masses approach equality and the square of the coupling constant increases indefinitely inversely as the difference in masses. In the symmetrical theories the resulting interaction is of the form

$$V_{12}=\frac{\tau_1\cdot\tau_2}{3}\left\{G^2S_{12}\left(\frac{1}{kr}+1\right)e^{-kr}+2F^2\sigma_1\cdot\sigma_2\left(\frac{2}{kr}-1\right)e^{-kr}\right\} \quad (1)$$

which is the same as would be obtained by differentiating the interaction with respect to the meson mass in the simple theories. The radial dependence of the central interaction is attractive at short ranges but repulsive at long ranges and thus would presumably lead to preferential forward scattering of high energy neutrons scattered by protons. In spite of the admitted conceptual difficulties concerning the limiting process by which (1) was obtained and the field-theoretic significance of the result, the simplicity of the result was sufficiently provoking to induce an attempt to compare the consequences of (1) with experiment. Preliminary results appear to indicate that agreement with the properties of both the proton-neutron and proton-proton system cannot be obtained if one employs in (1) the mass of cosmic-ray mesons.

A11. Possible Use of Thermal Noise for Low Temperature Thermometry. EDWARD GERJUOY AND A. THEODORE FORRESTER, *University of Southern California.*—The suggestion has recently been made that the Brownian motion of a quartz crystal be used to establish a low temperature thermodynamic scale.[1] The mean square noise voltage generated in any passive electrical network is $4kTR(f)df$, where $R(f)$ is the real part of the complex impedance. The noise voltage of a piezoelectric crystal, as well as that of ordinary resistors, must satisfy this relationship. The high impedance of a parallel resonant circuit at resonance suggests its use as a source of thermal noise. Subject to the condition that the output noise be representative of the low temperature to within 1 percent, a calculation was made which indicated that the lowest temperature measurable in this manner is certainly greater than 0.5°K. This limitation arises from the fact that the input impedance of the first tube must be much larger than the impedance of the resonant circuit. As a result there is an upper limit to the impedance at resonance which does not permit the noise in the tube to be exceeded at very low temperatures. This consideration applies equally well to piezoelectric crystals as to ordinary circuits.

[1] A. W. Lawson and E. A. Long, Phys. Rev. 70, 220 (1946).

A12. A Sensitive High Speed Radiation Thermocouple. HOWARD CARY* AND K. P. GEORGE, *National Technical Laboratories.*—The case of a thermocouple receiving modulated radiation is analyzed to determine the conditions yielding the maximum signal to noise ratio. It is concluded that: (*a*) vacuum operation is best, although the advantage is small at high modulation frequencies; (*b*) the optimum electrical resistance decreases with increasing frequency; (*c*) the thermal capacity of the thermoelectric leads must be made negligible by making the lead length less than a limiting value which varies inversely as the square root of the modulation frequency. A vacuum thermocouple designed for optimum performance at 10 c.p.s. is described.

The receiver is of gold foil 2.0 mm by 0.3 mm by 0.2μ thick, blackened with the equivalent of 0.2μ of gold. Taylor process bismuth and bismuth-tin thermocouple leads 0.2 mm long are used. To minimize thermal resistance of the receiver, four leads are soldered to the receiver at different points and connected to form two parallel thermojunctions with a combined resistance of one ohm. In agreement with theory, steady radiation of approximately 2×10^{-10} watt chopped at 10 c.p.s. and falling on the receiver produces an output signal equal to the r.m.s. noise of the thermocouple in a 1 c.p.s. band width.

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A13. A Proposed Experiment on the Ponderomotive Forces Exerted by Microwaves on Dielectric Media. OTTO HALPERN, *Los Alamos Laboratory.*—Some formulations[1] of relativistic electrodynamics lead to the result that an electromagnetic wave propagating itself in a dielectric medium exerts a force density given by the self-explanatory formula

$$\mathbf{f}=\frac{\epsilon\mu-1}{c^2}\frac{\partial \mathbf{S}}{\partial t}$$

The smallness of **f** has so far been considered to prevent experimental verification. The author proposes an experiment in which the force of a standing microwave in a $\lambda/4$ layer be measured preferably with a static magnetic field superimposed in the direction of the r. f. magnetic field. A (resonant) quartz-plate may be used as a piezoelectric indicator. This experiment if successful would permit for the first time to measure the actual time dependent of Poynting's vector.

[1] Cf., e.g., W. Pauli, *Relativitaets-Theorie.*

B1. An Intense Positive Ion Source for Solids. A. E. SHAW, *Argonne National Laboratory.*—A positive ion source for solids has been developed. A tungsten crucible containing the solid material and heated by electron bombardment produced intense beams of singly charged ions. Pt-Ir (15 percent) yielded 120μA, for 100 watts of electron power, La_2O_3 yielded 212μA, for 105 watts, and Sm_2O_3 yielded 40μA for 150 watts. A mass spectrographic analysis of the positive ions from a tungsten crucible containing La_2O_3 and UN revealed the presence of La^+, LaO^+, W^+, WO^+, U^+, UN^+, UO^+ and possibly UO_2^+. A similar analysis of the ions from Pt-Ir (15 percent) revealed the presence of all the singly charged isotopes of W, Pt, and Ir. It is anticipated that this source will find application in the mass deposition of isotopes. For example, in 10 minutes a deposit of 0.50 microgram of the completely resolved isotopes of samarium has been obtained.

B2. The Determination of Particle Size by the Low Angle Scattering of X-Rays. A. E. SMITH, *Shell Development Company.*—The particle sizes of samples of pure γ-Al_2O_3 heated at various temperatures from 650°C to 1000°C were determined by the low angle scattering of x-rays by using a Philips Geiger counter x-ray spectrometer. The mean crystallite sizes of the same materials were also determined by measurement of line broadening. The particle size and crystallite size, as measured by the above methods respectively, agree within the limit of experimental error. The surface calculated from the particle size distribution and mean crystallite size is in reasonable agreement with the surface measured by the Brunauer, Emmet, Teller method. The results are summarized in Table I.

TABLE I.

Heat Treatment	Line Broadening Mean a_0	Line Broadening Calculated Specific Surface, m^2/g	Low Angle Scattering Mean D	Low Angle Scattering Calculated Specific Surface, m^2/g	E.B.T. Measured Specific Surface, m^2/g
650°C— 6 hr.	86A	194	97A	198	172
900°C—36 hr.	—	—	143	156	93.5
1000°C—12 hr.	129	129	142	132	78

B3. Temperature Coefficient of Electrical Resistivity for Crystalline Selenium Containing Various Percentages of Bromine. WAYNE E. BLACKBURN, *Westinghouse Research Laboratories and University of Pittsburgh.*—The temperature coefficient of electrical resistance of brominated selenium over the temperature range, −30°C to 100°C, was found to be negative and variable. The electrical resistivities of the selenium samples varied by factors of three to twelve for the temperature range mentioned depending upon the bromine content. A reproducible hysteresis loop was obtained on the plot of resistivity *versus* temperature. A minimum in the plot of electrical resistivity *versus* bromine content was found with 0.007 percent bromine in selenium. Activation energies for freeing electrons obtained from the slopes of conductivity *versus* temperature plots indicate a dependence upon bromine content in the selenium.

B4. Viscous and Thermal Absorption of Sound as Relaxation Phenomena. CARL ECKART, *Marine Physical Laboratory.**—In discussing the absorption of sound, reference is often made to relaxation phenomena, as distinguished from the "classical" viscous and thermal dissipative processes. While this may be convenient, it is not a basic distinction. By using known formulae, it is shown that viscous dissipation of sound can be considered as a relaxation phenomenon, with relaxation time $\tau_\nu=4(\nu+\nu')/3\rho c^2$, where ν,ν' = ordinary and dilational coefficients of viscosity, ρ = density of fluid, and c = velocity of sound. Similarly, the relaxation time for thermal dissipation is $\tau_\kappa=\kappa/\rho c^2 S$, where κ = thermal conductivity, and S = specific heat at constant volume. In the case of an ideal monatomic gas, the ratio $s=\tau_\nu/\tau_\kappa$ has the value 1.05 and both τ_ν and τ_κ are of the order of magnitude of one mean free time. For actual gases, s ranges from 0.57 for argon to 7.2 for air. In the case of liquids, a normal value of s appears to be 10, but it ranges from 0.032 for mercury to 9700 for glycerol. For liquids, there seems to be no simple picture of the two relaxation times, and there is no adequate theory of the ratio s for either gases as liquids.

* This work represents one of the results of research carried out under contract with the Bureau of Ships and Office of Naval Research, Navy Department.

B5. Ionization Currents in Cylindrical Electrode Systems. G. W. JOHNSON, *University of California, Berkeley.*—Ionization currents were measured in pure hydrogen between concentric cylinders for pressures from 0.01 mm to 740 mm. Above 1 mm $1/p \log i/i_0$ is a function of X/p. At lower pressures it depends also on the pressure. Auxiliary anodes permitted estimates of the location of ionization in the field which confirmed the spatial distribution predicted by Morton.[1] Electrons released in the low and collected in the high field region resulted in about 10 percent less ionization than in the reverse case. In both cases the ionization was greater than given by Townsend's equation, as noted also at high pressures by Fisher and Weissler[2] for confocal paraboloids. The peaks of Morton's i/i_0 *vs.* p curves are identified with the pressure corresponding to the minimum sparking potential. Application of the back diffusion equation of Rice[3] in the form $i=AV/(V+B/p)$, where A and B are constants, permitted the evaluation of i_0 at higher pressures than hitherto has been possible. The present work makes possible the delineation of tables and curves to predict the electron multiplication in highly divergent fields.

[1] P. L. Morton, Phys. Rev. **70**, 358 (1946).
[2] L. H. Fisher and G. L. Weissler, Phys. Rev. **66**, 95 (1944).
[3] C. W. Rice, Phys. Rev. **70**, 228 (1946).

B6. Negative Corona in Freon-Air Mixtures at N.T.P. G. L. WEISSLER, *University of Southern California.*—In a point-to-plane corona gap of 3.1 cm, the onset potentials of the intermittent corona region were observed to be approximately constant, 6–7000 volts ($X/p\sim100$) for all freon air mixtures, whereas in pure freon this value changed abruptly to 12,650 volts ($X/p\sim200$). It is suggested that this is mainly due to a marked decrease in the first Townsend coefficient alpha, similar to the findings of Kruithoff and Penning[1] in A-Ne mixtures. Concentrations of freon of 10^{-4} to one percent were very similar to the known behavior of air,[2] mixtures from one to twenty percent showed in the intermittent corona region Trichel bursts, that indicated a very rapid decay in the amplitude of individual pulses. This is due to the formation of negative ions of freon decomposition products, such as chlorine and fluorine, which must be more stable at higher values of X/p (about 200) than those of oxygen (about 90). Also their probability of electron attachment is greater, since higher energy electrons can dissipate their excess in numerous vibrational states of freon, and in dissociation. Thus negative space charges must be stable much closer to the point and therefore be more efficient in choking off the discharge (decaying pulse size). Still higher concentrations inhibit proper avalanche formation such that Trichel bursts are barely observable. Current *vs.* potential curves show rapidly decreasing slopes with increasing freon content.

[1] Kruithoff and Penning, Physica **3**, 515 (1936); **4**, 430 (1937).
[2] Loeb, Kip, Hudson, and Bennett, Phys. Rev. **60**, 714 (1941).

B7. Positive Corona in Freon Air Mixture at N.T.P. E. I. MOHR, *University of Southern California (introduced by G. L. Weissler).*—In order to further our understanding of positive corona and thereby of spark breakdown, space charge phenomena and current *vs.* potential characteristics were studied in a 3.1-cm point-to-plane gap (point diameter $=\frac{1}{2}$ mm) in freon air mixtures. Streamer activity and strength increased going from pure air to 1 percent freon. Here the visual appearance of the corona changed markedly indicating that the discharge maintained itself solely by the streamer mechanism.[1] This seems due to a large increase in efficiency of photo-ionization in the gas without any appreciable change in the first Townsend coefficient α. As the freon content was increased to higher and higher values, the streamers became successively more degenerate until they could not be distinguished from burst pulses. This is compared to similar observations in air using needle points; here only incipient streamers can develop because of the rapid decrease of the field near the point resulting in too small values of $\int_{x_0}^{0}\alpha\,dx$. In our case the same was true because of the increased stability of negative freon decomposition product ions at higher values of X/p than those of O_2. The onset potentials of all observed phenomena were shifted to higher values and the current *vs.* potential curves showed decreasing slopes with increasing freon content. The changes in visual corona characteristics can be correlated to the space charge phenomena. The action of freon in suppressing discharge is ascribed to a gas mechanism, in contrast to the action of alcohol in A-counters,[2] which occurs at the cathode.

[1] L. B. Loeb and A. F. Kip, J. App. Phys. **10**, 142 (1939).
[2] C. G. and D. D. Montgomery, J. Frank. Inst. **231**, 447 (1941).

B8. A New Derivation of the Method of Characteristics for Axially Symmetrical Supersonic Flow. A. VAZSONYI, *North American Aviation, Inc. (introduced by S. H. Browne).*—Two-dimensional supersonic flow in nozzles and around airfoils and other bodies can be treated by the "method of characteristics." Recently this method has been extended to axially symmetrical flows. The differential equations using characteristic coordinates can be derived from the theory of hyperbolic partial differential equations. The derivation is laborious and does not clarify the basic physical principles involved. The alternative procedure proposed by the writer does not require an extensive knowledge of the theory of partial differential equations. Bernoulli's equation, the continuity equation, and the kinematical expression for the rotation are written down using intrinsic coordinates (coordinates along streamlines and normal to streamlines). The differential change in velocity can be expressed as a function of the differential distance, the local value of the rotation, Mach number, distance from the axis of the flow, differential change in flow direction, and the tangential and normal derivatives of the velocity. The last two quantities drop out when changes along a Mach line are considered, and the basic equation of the method of characteristics is obtained. It is believed that this new derivation gives a better physical understanding of the method.

B9. Atomization of Liquids. J. M. SCHMIDT, *California Institute of Technology.*—Various theories of the formation of droplets in pressure injection and air stream atomization of liquids are discussed. A number of experimental methods are described for the measurement of mean droplet sizes

as well as droplet size distributions in atomized liquids. Some of the methods used are high speed photography, impingement of the droplets on smoked plates, and photometric measurements of light absorption by sprays. Droplet size distributions are given for various liquids atomized under various conditions. In sprays of hydrocarbon fuels, injected under a pressure of 50 lb. per in.^{2} through hollow cone injectors into air streams moving with velocities of 20 ft. per sec., mean droplet diameters as small as 45 microns have been measured.

B10. Escape from the Earth by Multiple-Step Rockets. MARTIN SUMMERFIELD, *California Institute of Technology.*—Recent achievements in rocket vehicle performance as exemplified by the "V-2" rocket and the "WAC Corporal" rocket have focused attention on the physical factors limiting the velocities attainable in this manner. This paper deals with the question of escape from the surface of the earth, with special reference to four missions: (1) an earth-satellite revolving around the earth just above the atmosphere, (2) a "stationary" earth-satellite whose angular velocity equals that of the earth, (3) a vehicle that completely escapes the earth, (4) a vehicle that escapes the solar system. General performance equations are presented that bring out the effects of the following important parameters: jet exhaust velocity, ratio of propellant mass to gross mass, time of burning, and a drag factor. It is shown that, if exhaust velocities are limited by the energies produced by chemical reactions, it is doubtful that a single rocket can be constructed that is capable of leaving the earth. By means of multiple-step rockets much greater velocities can be imparted to the vehicle. Several cases of multiple-step escape rockets are calculated, and their characteristics discussed. Special emphasis is placed on the importance of determining the optimum number of steps.

B11. Problems in the Application of Nuclear Energy to Rocket Propulsion. H. S. SEIFERT AND M. M. MILLS, *California Institute of Technology.*—Consideration is given to the basic physical limitations involved in the application of nuclear energy sources to the propulsion of rockets. Quantitative estimates are made of the performance parameter *specific impulse* (impulse transmitted to the rocket per unit mass of expelled propellant) for the cases where propulsion is accomplished by: (a) photons, (b) fission fragments, and (c) an inert working fluid. Because of the fundamental difference between chemical rockets, in which the propellant is used both as a source of energy and as the mass to be ejected in obtaining thrust, and a "nuclear" rocket of type (c) above, in which these two functions may be separated, there exists an optimum ratio of payload or nonexpendable mass to working fluid or expendable mass, which differs for the two types of rockets. This was first pointed out by Ackeret.*

* J. Ackeret, Helv. Phys. Acta **19**, 103 (1946).

B12. Gamma-Radiation from Be^9+H^1. C. C. LAURITSEN, T. LAURITSEN, AND W. A. FOWLER, *California Institute of Technology.*—Further investigations have been made of the gamma-radiation from Be^9 bombarded by protons[1] particularly in the region of the resonances in the thin target excitation curve near 0.975 and 1.06 Mev. The first resonance has been found to have a width of 100 Kev. The thick target yield is 2×10^{-8} quanta per proton, so that $\omega\Gamma_\gamma\Gamma_p/\Gamma$ equals 20 volts. The second resonance width is less than 10 Kev, higher resolution in proton energies and thinner targets being necessary to complete this determination. The thick target yield is 2×10^{-9} quanta per proton so that $\omega\Gamma_\gamma\Gamma_p/\Gamma$ equals 2 volts. Measurements of the secondary pairs from a thick target bombarded at 1.1 Mev indicate radiation of energy 7.2 ± 0.2 Mev. Absorption measurements indicate no soft radiation. Thus the radiation from the strong wide resonance, at least, arises from a single transition from the compound nucleus B^{10} to its ground state. The width in this case must be due to competition with the re-emission of *s*-wave protons and probably with the emission of deuterons and alpha-particles. The narrow resonance must arise from *p*-wave capture with alpha and deuteron emission relatively improbable or forbidden. This work was carried on under contract with the Office of Naval Research.

[1] W. J. Hushley, Phys. Rev. **67**, 34 (1945).