National Academy of Sciences

Abstracts of Papers Presented at the Autumn Meeting, 2–4 November 1955, California Institute of Technology, Pasadena

Stellar Magnetism, a Summary

The gradual accumulation of magnetic data on the sharp-line peculiar A-type stars over an interval of 9 years now permits a classification of these objects into four closely related groups, depending on the main characteristics of the magnetic variation: (i) 1-week magnetic reversers of large amplitude; (ii) slower, quasi-periodic variables; (iii) rapid irregular fluctuators; and (iv) slow irregular fluctuators.

The four stars of group (i) show reversing magnetic fields of large and nearly identical amplitude, with remarkably similar periods; all are of spectral type AOpm. The slower variables of group (ii) have ultra-sharp lines, later spectral types (FOpm), and cycles ranging up to 226 days. A majority of the magnetic stars, being irregular, fall into groups (iii) and (iv). Again, the slower fluctuators tend to have the sharper lines and generally later spectral types. The outstanding spectrum variables are confined to groups (i) and (ii) and to a group (i′) of short period, with lines too broad for measurement of the Zeeman effect.

Intrinsic hydromagnetic fluctuations evidently occur in the surface layers of most of these stars. A beginning can be made on the interpretation of these results by analogy with the solar magnetic cycle and the hydromagnetic processes observed in some detail on the sun. The enhanced magnetic activity observed among stars of spectral type A and early F is in accord with the "dynamo theory" of Elsasser, which requires both rapid axial rotation and the action of Coriolis forces on convective material. Stars of earlier type do not have hydrogen convective layers; those of later type do not rotate rapidly.

HORACE W. BABCOCK
Mount Wilson and Palomar Observatories

New Long-Period Waves Recorded with a Strain Seismograph

A seismogram of the Kamchatka earthquake of 4 November 1952 written by an electromagnetic strain seismograph having a galvanometer of 3 minutes period has revealed three waves or oscillations not previously known. These include a wavelet identified as $P'R_1$, a Rayleigh wave generated at the antipodal point; a long-period wavelet of approximately 50 minutes period; and a still longer period pulse of many hours' duration. The long-period wavelet may represent a free vibration of the earth, whereas the long-period pulse may be the readjustment of the world strain pattern in response to the strain relief at the source.

HUGO BENIOFF
Seismological Laboratory, California Institute of Technology

Single Quartz Crystal Point-Focusing X-ray Monochromator

A point-focusing x-ray monochromator that uses Bragg reflection from a single lamina of quartz bent in such a way that its atomic planes are given two principal radii of curvature has been constructed for use in low-angle diffraction studies. It was found that the crystal reflects 2.78 percent of the incident Cu $K\alpha_1$ radiation into a converging beam 1 m long, with a resolution of better than ½ mm, except for a very faint halo. The instrument has been used to obtain diffraction patterns from normal and sickle-cell human hemoglobin and also from southern bean mosaic virus. The speed of the present instrument is roughly 200 times that of the equivalent pinhole collimating system. A similar but still faster instrument is being constructed.

This research was sponsored by the U.S. Atomic Energy Commission and the Office of Naval Research.

DWIGHT W. BERREMAN
California Institute of Technology
Present address: *Stanford Research Institute*

On the Method of Lighthill

In a paper ["A technique for rendering approximate solutions to physical problems uniformly valid, *Phil. Mag.* **40**, 1179 (1949)] M. J. Lighthill obtained formal expansions in powers of the parameter α of the solutions of differential equations of the form $(x+\alpha u)\,du/dx = r(x) = u\,q(x)$ which satisfy an initial condition $u(1) = a$. Essential to the method is the fact that in order to obtain approximations useful in the neighborhood of $x = 0$ both the independent variable x and the dependent variable u are expanded in powers of α. W. A. Wasow showed that under certain conditions on $r(x)$ and $q(x)$, as well as on the solution of limiting equation $x\,du/dx = r - uq$, these expansions were convergent. In the present paper the convergence is discussed for more general equations, removing unessential assumptions.

H. F. BOHNENBLUST
California Institute of Technology

Retention and Properties of S^{35}-Labeled Hemocyanin in the Livers of Normal and Immunized Rabbits

The S^{35} label of soluble sulfanilic-azo-hemocyanin antigen is detectable in the livers of injected animals for at least 4 months after a single intravenous injection or after the last of a series of nine injections. Preliminary data suggest that less antigen persists in livers of animals that received multiple injections than in those that received only a single injection. An initial injection of labeled antigen, followed by several injections of unlabeled antigen results in a rapid loss of labeled antigen from livers when the concentration of circulating antibody reaches about 100 μg/ml of serum. The retained antigen rapidly loses its ability to form insoluble complexes with precipitating antibody but retains its ability to combine with antibody and to form soluble complexes. The physical properties of the retained antigen are different from those of the injected material. It is suggested that perhaps these antigen fragments that are retained are the actual templates that are involved in antibody formation.

DAN H. CAMPBELL
JUSTINE S. GARVEY
California Institute of Technology

Alpha-Particle Decay of Heavy Nuclei

Recent experiments by Asaro and Perlman on the energies and intensities of alpha-particles emitted by heavy nuclei show systematic trends with atomic number in the intensities of the fine structure components leading to excited states of the daughter nuclei. These excited states have been interpreted as the rotational excitations of the (ellipsoidal) nucleus according to the ideas of A. Bohr and others. The alpha-particle intensities to these states can then be interpreted in terms of the angular distribution of the alpha-particles relative to the orientation of the symmetry axis of the ellipsoidal nucleus. The present work concerns a new formulation of the classical (WKB) approximation suitable for the treatment of the penetration of alpha-particles through a nonspherical barrier in a nonspherical potential. It is found that the amplitude for barrier penetration in any direction can be viewed as a result of tunneling outward along the direction of steepest descent with the appropriate exponential decrease in amplitude, together with a transverse

diffusion process that is the counterpart of the usual centrifugal barrier.

As a result of calculations by this method, it is found that the systematic decrease with Z of the intensity of the $l=4$ component in the alpha-particle angular distribution may result from a corresponding systematic growth in a P_4 distortion of the nuclear surface. Such a distortion of negative sign and amplitude only 3 or 4 percent of the nuclear radius can lead to a vanishing $l=4$ component in the alpha-decay spectrum.

This work was assisted by the joint program of the U.S. Office of Naval Research and the Atomic Energy Commission.

ROBERT F. CHRISTY
California Institute of Technology

Formulas for Pressure on Cones at Supersonic Speed

Formulas are given for calculating the pressure on slender cones at zero incidence in supersonic flow. A different formula is given for each of the speed ranges, transonic, supersonic, and hypersonic. An estimate of the ranges of cone angle and Mach number in which the formulas can be used is given, together with estimates of the error incurred.

J. D. COLE
California Institute of Technology

Delayed Effects of Mutagenic Agents

The detection of mutagenic effects from radiation, atomic fallout or chemical agents may not always be as simple as might at first appear. It can reasonably be expected that there will always be some mutations, whether induced or spontaneous, which will find expression only in the presence of a special combination of already established genes, or simultaneous mutations whose effects will be mutually contingent on one another. In either case somatic appearance of a trait in which a fresh mutation is involved is likely to be considerably delayed.

This aspect of the matter is considered in a study of the descendants of mice that have been subjected to a single treatment with nitrogen mustard, a commonly employed mutagenic agent. Some of the descendants have shown deviations that suggest simple mutational changes (such as pink eyes or extra teeth) that can be analyzed in the usual way. Others (such as syndactyly and some visceral anomalies) are more complex and occur in what at first sight might seem to be an erratic fashion. Many of the latter are presumably due to cumulative effects of several initially independent but mutually interacting genes which can be brought into effective relationship only after several generations. A significant inference from the study is that genetic tests extending over no more than two or three generations are by no means adequate for detection of all the mutations that may have occurred as a result of any single treatment.

C. H. DANFORTH
Stanford University

Study of Atomic Recombination Reactions by Shock Waves and by Flash Lamps

The rate of the termolecular atomic recombination process

$$X + X + M \rightarrow X_2 + M,$$
$$d(X_2)/dt = k_R(X)^2(M)$$

can be measured at room temperature by the flash photolysis method. In the foregoing equation, X represents a halogen atom and M any gas molecule. The rate at high temperatures can be computed from the rate of the reverse dissociation reaction as measured by the shock-wave method.

As a result of work in several laboratories, the present status of our knowledge of the foregoing reaction is the following: When X is iodine and M is argon, $k_{R,A} = 2.2 \times 10^9$ lit^2 mole^{-2} sec^{-1} at 300°K and 0.5×10^9 at 1200°K. When M is molecular iodine itself, $k_{R,I2} = 1.3 \times 10^{12}$ at 300°K and is less than 1.5×10^{10} at 1200°K. The remarkable efficiency of iodine as a third body at room temperature is presumably due to the transient formation of I_3. The decrease in the ratio $k_{R,I2}/k_{R,A}$ with increasing temperature is presumably due to the thermal instability of I_3.

It is now clear that, in general, k_R increases with increasing molecular complexity of M and decreases with increasing temperature. An attractive hypothesis that requires further investigation is that the negative temperature coefficient of k_R is greater, the greater the value of k_R itself.

The available results for X being bromine are also in agreement with the foregoing statements.

N. DAVIDSON, D. BRITTON, D. BUNKER
G. SCHOTT, W. GEHMAN
California Institute of Technology

On the Character of Differential Equations Representing Wave Propagation

Partial differential equations for functions of space and time represent propagation phenomena if they are of the hyperbolic type. The distinction between hyperbolic and other types is easily formulated, except in cases when the "characteristic elements" are multiple. Since such multiplicities do often occur in physics and mechanics, it is important to clarify this situation. Such clarification is indicated in the paper. Various phenomena such as Huyghens' principle are connected with this subject.

R. COURANT
New York University

A Protein Whose Configuration Is Controlled by a Specific Cofactor

Some strains of bacteriophage must be activated by cofactor before they can adsorb to their bacterial hosts. Up to the present time, the only compounds shown to possess cofactor activity have been certain amino acids and amino acid analogs.

It is shown [G. Sato, thesis, California Institute of Technology (1955)] that urea, a well-known denaturing agent, is capable of activating cofactor requiring phage. Urea also kills the phage. Experiments are performed to characterize the properties of urea-activated phage, in regard to stability of urea-induced adsorbability and in regard to adsorption rate. The kinetics of the urea-activation process and of the urea-killing process have been studied in detail. Both processes depend on concentration of urea, temperature, and pH in a manner similar to denaturation of protein by urea.

It is concluded that urea effects the activation of phage by changing the configuration of the protein of the phage-adsorption organ. It is further postulated that the action of cofactors consists in a change in the configuration of phage protein.

It is suggested that many other pharmacological phenomena involve the reversible changes of configuration of a protein that is capable of existing in several states, the equilibrium between these states being strongly dependent on changes in concentrations of specific substances of low molecular weight.

MAX DELBRÜCK
California Institute of Technology
GORDON SATO
University of California, Berkeley

D-alpha-Hydroxy Acids in Biological Systems

It has been shown in our laboratory that D-lactic acid is an essential metabolite for *Lactobacillus casei* 280–16, a mutant of the wild form of *L. casei*, and that the activity of yeast extract, butter, and wool wax appears to be due largely to their content of D-lactic or other D-alpha-hydroxy acids. It has been reported that yeast and brain cerebronic acids (2-hydroxytetracosanoic, 2-hydroxyhexacosanoic, and 2-hydroxydocosanoic acids), the alpha-hydroxy acids from wool wax, and 2-hydroxypentadecanoic acid (derived from ustilic acid) are of the D-configuration.

Active compounds include the alpha-hydroxy derivatives of the following DL-acids: butyric, capric, caproic, caprylic, lauric, myristic, valeric, mandelic, and phenyllactic acids. Inactive compounds include beta-hydroxy acids, alpha-keto acids, and alpha, beta unsaturated acids. Of the nine DL-1,2-alkanediols studied dodecanediol markedly stimulated the growth of *L. casei* 280–16 in hydroxy acid-free medium, whereas tetradecanediol and hexadecan-diol markedly inhibited growth in a DL-lactic acid-containing medium.

It has been concluded from this work that alpha-hydroxy acids of natural lipids are predominantly of the D-configuration, may serve as metabolic precursors to long-chain D-alpha-hydroxy acids of essential lipids, and may play some role in the nutrition of mammals as well as bacteria. An over-all mechanism has been proposed for the formation and utilization of D-alpha-hydroxy acids.

M. S. DUNN, M. N. CAMIEN, E. GELLER
University of California, Los Angeles

Singularities of Axially Symmetric Potentials

A generalized axially symmetric potential (s.p.) is a solution of the partial differential equation $u_{xx} + u_{yy} + ky^{-1} u_y = 0$, which is an even function of y and a regular function of x and y for sufficiently small y and some x. An s.p. is uniquely determined by its (analytic) values on the x-axis. Given an analytic function of x, regular on some interval of the x-axis, the s.p. that reduces on the x-axis to the given function will be regular in a unique maximal simply connected region in the x,y plane which is convex in the y direction. The main result of the study is that the maximal region of regularity is independent of k (that is, of the number of dimensions).

A. ERDÉLYI
California Institute of Technology

Active Metal Intermediates in Coulometric Analysis

Coulometric titrations performed with constant-current techniques involve the production of chemical reagents by electrolysis. If a reagent is generated with current efficiency of 100 percent, the time of electrolysis is an exact measure of the amount of substance titrated.

Some active metals can be deposited quantitatively by electrolysis. After a metal deposit has reacted chemically with an oxidizing agent in solution, the excess metal can be stripped off electrolytically. With constant current, the difference between depositing and stripping time is proportional to the amount of oxidant in the sample.

Copper metal has been plated from cuprous halide solutions and has been used to titrate cupric copper and ferric iron samples with good analytic accuracy. In order to produce a more powerful reducing agent, metal amalgams are being prepared and decomposed electrolytically. Zinc and cadmium systems have been investigated, and studies on other amalgams are in progress.

PAUL S. FARRINGTON
University of California, Los Angeles

Synthesis of the Elements in Stars

The nuclear reactions by which the stable elements may be synthesized from hydrogen in stellar interiors have been enumerated and studied in some detail. The results lend support to the hypothesis that a process of continuous synthesis as stars evolve, eject material into interstellar space, and recondense may be the source of the observed universal abundances of the elements.

On this point of view, helium is formed by hydrogen burning in main sequence stars. The nuclei C^{12}, O^{16}, and Ne^{20} are formed from helium in the condensed, hydrogen-exhausted cores of red giant stars. The eventual exhaustion of the helium leads to reactions among still heavier nuclei, with the ultimate formation of the most stable nuclei, those of the metallic elements (Ti to Zn with a maximum at Fe^{56}). In second generation stars, hydrogen and helium reactions with the C^{12}, O^{16}, and Ne^{20} produce the stable isotopes of these nuclei as well as of N and F. In the giant stage, the interaction of helium with the nuclei C^{13}, O^{17}, and Ne^{21} leads to the production of neutrons. If large proportions of the metals are present, as in Population I stars, the neutrons are captured by the metallic nuclei at thermal energies of ~ 15 kev leading to the successive synthesis of the heavy elements up to Pb. Where the metals are rare, as in Population II stars, capture of the neutrons by the light elements leads to the synthesis of the intermediate elements from Na to Ti.

D, Li, Be, B and the natural radioactive alpha-emitters cannot be produced in stellar interiors and are possibly synthesized in "spots" on the surfaces of variable magnetic stars by a low-energy component (10 to 100 Mev) of the cosmic radiation produced in these spots. Critical tests of the synthesis mechanism proposed will depend on more accurate and extensive measurements of the cross sections of the nuclear reactions involved.

This investigation has been made in collaboration with G. R. and E. M. Burbidge and follows in large measure the work of E. E. Salpeter, F. Hoyle, and A. G. W. Cameron.

WILLIAM A. FOWLER
California Institute of Technology

Evolutionary Trends in Abundances of the Chemical Elements

During the last few years various aspects of the theory of nuclear transmutation in stars have been developed. Astrophysical estimates of the composition of peculiar and normal stars confirm some of these predictions and make it possible that the heavy-element content of our galaxy has changed appreciably.

Thermonuclear processes in the main-sequence stars result in a secular increase of the He/H ratio and a change in the C/N and C^{12}/C^{13} ratios. At higher central temperatures C, O, Ne, Si, and so forth, can be formed by alpha-particle reactions. In addition, a surprisingly large supply of neutrons comes from $C^{13}(\alpha, n)\ O^{16}$, and may build heavier elements. Certain reactions may occur at the surfaces of the stars.

Some examples of types of stars that show all the afore-mentioned effects will be given. Stars of low luminosity, recently found at Palomar, show convincing enhancement of both He and N. The most startling effect is the presence of Tc, discovered by Merrill in certain red giants, which has a half-life of only 300,000 years.

Modern astrophysical theories suggest that stars are being formed out of interstellar gas. Recent observations have shown that various types of old stars (Population II) are losing matter into space. Newly formed stars of Population I can be expected to show higher abundances of the heavy elements. Observations of spectra of subluminous stars of Population II confirm this prediction. Abundances in the earth and sun represent a relatively late state of evolution of the elements.

JESSE L. GREENSTEIN
Mount Wilson and Palomar Observatories

Structure of Human Intellect

Multiple-factor theory provides a convenient model for the description of human abilities in terms of a set of vectors in n dimensions. Analysis of individual differences among young, superior adults shows that at least 40 dimensions are required to account for the patterns of intercorrelations among scores from tests involving intellectual tasks.

The intellectual factors show a strong tendency to fall into a system, including a small group of memory factors and four groups of thinking factors. The thinking-ability factors can be distinguished, first, as cognition (discovery) abilities, action (production) abilities, and evaluation abilities. The action abilities can be further differentiated in terms of convergent thinking and divergent thinking.

Within each of the five groups, there is a common tendency for factors to come in sets of three parallel factors, depending on the test content—perceived figures, structural elements (such as letters or numbers), and meanings (concepts or ideas).

A survey of the factors in such a system indicates a number of vacant cells where possibly undiscovered factors exist. With such vacancies filled, the number of intellectual factors would approach 60. The implications for the psychology of thinking and for the practice of intelligence testing are very significant.

J. P. GUILFORD
University of Southern California

Nuclear Energy Levels

The conspicuous success of atomic spectroscopy in revealing the structure of the atom justifies the expectation that the analogous study of nuclear spectroscopy may be of comparable utility in elucidating the structure of atomic nuclei. Presently available information on the energy levels of light nuclei is sufficiently detailed to make it clear that the problem is one of much greater complexity than might have been thought but, nevertheless, gives considerable hope that some features at least can be understood. Unlike the atomic case, the energies of nuclear-excited states do not appear to admit expression in any simple mathematical form: spacings between levels in light nuclei may vary from some millions down to some thousands of electron volts, with considerable individual deviations from a general tendency for smaller separations at higher excitations. On the other hand, a striking feature is observed in the close similarity between energy-level arrangements in isobars, suggesting that it is the total number of particles in a nucleus that determines its structure rather than the somewhat incidental nuclear charge. Thus, whereas the

nuclear spectra of Li^7 and Be^7 correspond in all essentials, those of Li^7 and Li^6 are entirely different. This observation, which has been confirmed for many isobaric sets, has an important bearing on the theory of forces between the neutrons and protons that make up the nucleus.

Other information derived from energy-level studies indicates that the concept of a "shell" structure, which has had conspicuous success in accounting for many features of the normal states of nuclei, may have useful applications in the excited states as well. Attempts to associate known energy levels with those predicted by this model constitute an important fraction of current work in the field.

This work was assisted by the joint program of the U.S. Office of Naval Research and the Atomic Energy Commission.

T. LAURITSEN
California Institute of Technology

Energy of Earthquakes

Gutenberg and Richter have revised equations that permit the calculation of earthquake energy E (in ergs), probably within 1 unit of log E. I find that in the average year 1904 to 1954, log $E = 25.0$; the energy released in earthquakes is less than 1 percent of that released in the earth by radioactive processes. At all focal depths h, the frequency of earthquakes releasing a given energy E decreases nearly exponentially with increasing E. The average annual number of shallow shocks ($h \leq 60$ km) in a range of ¼ unit of log E increases from 0.04 for the largest known (log $E = 25.2 \pm$) to several hundred thousand producing motion near the epicenter barely above the usual unrest of the ground (log $E = 10.0 \pm$). About two-thirds of all energy is released in the crust above 35 km, only 3 to 4 percent below 300 km. Shocks originating deeper than 300 km are known in the relatively narrow circum-Pacific and Alpide belts only; there the energy release has a minimum at depths near 300 km and secondary maxima near 350 to 400 and 550 to 650 km. With increasing h, the maximum energy E^* found for a single shock decreases:

h	20	150	350	650	720 km
log E^*	25.2	25.0	24.5	23.8	22.6

No shocks are known below 720 km; this could be caused by decrease of the apparent viscosity coefficient from 10^{22} to 10^{23} poises in the crustal layers to about 10^{20} poises below 700 km.

BENO GUTENBERG
Seismological Laboratory,
California Institute of Technology

Energy Characteristics of Strong-Motion Earthquakes Pertinent to the Design of Structures

The engineering problem of designing structures to resist strong earthquake ground motion requires some reliable method of estimating the amount of strength required by a structure to enable it to withstand earthquake motion. Such a method must take into account the statistical aspects of the problem based on recorded data of past earthquakes, and also the influence of the physical properties of the structures it is proposed to build. For linear structures with multiple degrees of freedom it is found from recorded strong ground motions that the spectrum of the maximum vibrational energy per mode exhibits certain characteristics from which can be established an upper bound for the maximum vibrational energy that the structure as a whole can experience. The properties of the upper bound are such that for structures of the type usually encountered in practice the maximum energy input is independent, in a statistical sense, of the structural strength and stiffness and depends in a simple way on the mass and damping of the structure. A suggested criterion for designing a structure is that it be able to absorb the maximum energy input, either elastically or plastically, without failure. This leads to results differing from those given by design procedures currently in use. Comparison with observed behavior of structures during earthquakes indicates satisfactory agreement with the results computed by this method.

GEORGE W. HOUSNER
California Institute of Technology

Energy Transfer Processes in Unimolecular Reactions

The Lindemann (1922) mechanism of unimolecular reactions consists of three different physical processes: activation by collision, deactivation by collision, and reaction of isolated activated molecules. The process of activation by collision may be expressed (Tolman, 1926) in terms of Boltzmann factors and the process of deactivation by collision. A given model of the activated molecule and the reaction process (for example, Rice, Ramsperger, Kassel, 1927; Glasstone, Laidler, Eyring, 1940; N. B. Slater, 1938–53; Marcus, 1952) gives rise to the Boltzmann factors and reaction rates of excited molecules; entirely separate physical considerations are required for the problem of energy transfer by collision.

In quantitative applications of the usual theories, use is made of Tolman's crude order-of-magnitude approximation; that is, deactivation occurs upon every collision. However, use can be made of the Lindemann mechanism in its sum-over-state form in which the probability function and the reaction function are left completely general and unspecified. Several general statements can be made concerning the energy-transfer function in terms of observed reaction-rate data. Tests of these general theorems against experimental data indicate that deactivation does not occur upon every collision, that the rate of deactivation varies with the degree of activation of the reactant molecule, and that this variation with degree of excitation is different from one foreign gas to another.

HAROLD S. JOHNSTON
Stanford University

Coordination of Alkynes with Silver Ion

The reaction of 3-hexyne with aqueous silver nitrate at different concentrations but all at unit ionic strength was investigated by a distribution method in which the organic solvent was carbon tetrachloride. A plot of the equilibrium constant against silver-ion concentration has a slight upward curvature, indicating that the principal complex is $Un.Ag^+$ (where Un represents an alkyne) and a minor complex is $Un.2Ag^+$. The respective constants are $K_1 = 19.1$ and $K_2 = 0.22$. Since these constants are calculated from concentrations, they are not thermodynamic constants.

The change in solubility of a number of alkynes in aqueous solutions at $\mu = 1$ with a rise in silver-ion concentration is not linear, and again the plots have a slight upward curvature. Here also a second complex is involved. By the method of least squares, values of K_1 and K_2 have been calculated. For 3-hexyne these are, respectively, 17.3 and 0.36, in satisfactory agreement with the values obtained by the distribution method.

Alkynes having methyl substituents at α-carbon atoms have constants that differ little from those of 3-hexyne. Without any trend K_1 varies from 11.9 to 23.4, and K_2 from 0.21 to 0.53 among 3-hexyne, 2-methyl-3-hexyne, 2,2-dimethyl-3-hexyne, 2,2,5-trimethyl-3-hexyne, 2,2,5,5-tetramethyl-3-hexyne and 2-heptyne.

An approximation to a thermodynamic equilibrium constant can be obtained when some simplifying assumptions are made. These constants have a definite trend and give realistic ΔH values, whereas K_1 gives unrealistic values for ΔH.

HOWARD J. LUCAS
W. SMITH DORSEY
GEORGE K. HELMKAMP
California Institute of Technology

Differential Response of Eye and Optic Pathways to Intensity and Wavelength

An attempt has been made to localize upon the eyeball of the cat the origin of the components of the electroretinogram, in particular the *a*- and *b*-waves. Through scleral slits or holes recording has been accomplished from several points on the bulbus in such a manner as to reveal by phase reversal techniques and pattern of response suggestions as to the origin of the ERG components. Variations in the stimulus parameters of intensity and wavelength have been utilized. Simultaneous recordings from the eye, optic nerve, optic tract, lateral geniculate bodies, and cortex provide differential response forms, and latencies that make it appear likely that an *a*-, rather than a *b*-, process triggers the optic nerve discharge. The possible role and origin of each of these components is discussed.

DONALD B. LINDSLEY
ROY S. GIFFITHS
University of California, Los Angeles,
and *Long Beach Veterans*
Administration Hospital

Electromotive Force Centrifuge—Factors Affecting Accuracy

The electromotive force centrifuge consists of a simple galvanic cell with electrodes at radii r_1 and r_2 in a rotor that turns at a rate of n rev/sec. Under these conditions a potential E develops, which for the cell that may be represented by

$$\mathrm{Pt;\ I_2,\ KI,\ I_2;\ Pt}$$

is given by the equation

$$E\,F = 2\pi^2 n^2\,(r_2^2 - r_1^2)\,[t_K\ (M_{KI} - \overline{V}_{KI\rho}) - (M_{I2} - \overline{V}_{I\rho})]$$

in which t_K is the transference number of the potassium-ion constituent, M_{KI} and M_{I2} are molecular weights, $\overline{V}_{KI}$ and $\overline{V}_{I2}$ are partial molal volumes, and ρ is the density of the solution. The phenomenon has interest since it may be used as a means of determining transference numbers particularly for electrolytes in nonaqueous solvents. Since the electrodes do not have to carry appreciable currents, as in most other methods for determining transference numbers, disturbances due to joule heat are avoided.

The early work on the emf centrifuge was done by des Coudres (1893) and by Tolman (1911). Our work at the Rockefeller Institute has been devoted largely to the attempt to make the instrument one of precision. To this end improvements have been made in the measurement of the speed of rotation, in the determination of densities of the solutions and of the partial molal volumes, and in the elimination of the effects on the potentials of suspended dust particles. It has been found that the foregoing equation must be modified for the effect of the complex formed between KI and I_2, and an independent determination of the composition of the complex is obtained.

Recent work has been concerned with improvements in the design of the commutator connecting the rotating cell with the potentiometer, with elimination of effects resulting from uncertainties in the values of the radii, r, and studies of the adiabatic heat effects and persisting temperature gradients on the measured potentials.

D. A. MacInnes
Robert L. Kay
Rockefeller Institute for Medical Research

Some Properties of the Apparent Expansion of the Universe

A survey of all available observational data on the apparent expansion of the universe is made. These data consist of (i) redshifts of 620 extragalactic field nebulae and 26 distant clusters of nebulae obtained by Humason at the Mount Wilson and Palomar Observatories, (ii) redshifts of 300 field nebulae obtained by Mayall at the Lick Observatory (114 nebulae are in common with the Mount Wilson–Palomar list), and (iii) apparent magnitudes obtained by Pettit of most of these nebulae.

Discussion of this material gives the following five conclusions. (i) The data for the field nebulae show the relationship between the apparent magnitudes (corrected for Pettit's variable photometer apertures and for the selective effects of redshifts) and the log of the redshifts to be $m_c = (5.028 \pm .116)\ \log\ c\ \Delta\lambda/\lambda_0 + \text{const.}$ A coefficient of exactly 5 indicates a linear redshift-"distance" relationship if no general internebular obscuration is present. (ii) The mean absolute magnitude of all nebular classes, except Irr, is the same within the probable error of the data. (iii) The apparent expansion appears to be isotropic. (iv) Data for the clusters with $c\Delta\lambda/\lambda_0 > 0.1$ show an apparently significant departure from a linear expansion in the direction of deceleration. This result is not conclusively established because of uncertainties in the effects of redshifts on apparent magnitudes, the change in M_{bol} of nebulae owing to evolution, and the consequences of the Stebbins-Whitford effect. The data, corrected with estimated values for these effects, give $\ddot{R}_0/H\dot{R}_0 = -2.6$ where R_0 is a characteristic length and H is the Hubble redshift parameter. (v) Evaluation of H gives a value of 180 km/sec 10^6 psc or $H^{-1} = 5.4 \times 10^9$ years. This value is provisional and may be uncertain by 20 percent. If $\ddot{R}_0$ is negative, then the "age of the universe" is less than H^{-1}.

N. U. Mayall
Lick Observatory
A. R. Sandage
M. L. Humason
Mount Wilson and Palomar Observatories

Neural Basis of Bilateral Perceptual Integration

Extensive sensory, motor, and psychological tests have failed to demonstrate any clear-cut functional deficiencies following complete surgical section or agenesis of the corpus callosum in man. The findings are difficult to understand in view of the very large size of this tract and the fact that it serves as the principal connection between the cortices of the two hemispheres.

In recent experiments with cats it has been possible to demonstrate a definite function for the corpus callosum in mediating the transfer of perceptual data from one side of the brain to the other. In these experiments the crossed optic fibers were destroyed at the optic chiasma, thereby restricting the visual input from the two eyes to their respective brain-halves. The left hemisphere then received retinal impulses from only the left eye, and the right hemisphere from only the right eye. After the cats had been taught simple pattern discriminations with a mask covering one eye, the mask was shifted to the opposite eye. Transfer of the learned discrimination to the untrained eye was almost perfect with the callosum intact but was entirely absent in cases in which the corpus callosum had been sectioned prior to training. Indeed, with the corpus callosum divided, completely conflicting responses could be established with the two separate eyes with no evidence of interference. Further work indicates that visual transfer can still occur when as little as 20 percent of the total cross-sectional area of the corpus callosum is left unsectioned at the posterior end. Conversely transfer fails when the posterior half or more is transected.

Ronald E. Myers
California Institute of Technology

NGC 1275, an Example of Colliding Galaxies

Several radio-sources have now been identified with colliding galaxies. Only weak nonthermal radio emission results from a close approach of two galaxies, which may lead to spectacular tidal distortion. Very strong emission is produced only by a direct collision. Only one of the sources of this type, NGC 1275, is of sufficient apparent size to permit a detailed investigation.

Spectroscopic observations, guided by photographs by Baade with various plate-filter combinations, show that the object consists of two galaxies, a tightly wound spiral of early type, and a highly distorted spiral of late type. North of the nucleus the late-type system is seen in front of the early-type system. A low excitation emission spectrum with double lines indicates that the late-type galaxy moves with a radial velocity of about 3000 km/sec toward the early-type galaxy. Near the nucleus and farther to the south, this spectrum is replaced by a high excitation spectrum with single asymmetrical lines of great width. These results suggest that the actual collision is now in progress in the northern part of the system. The interaction in the southern part is finished but has left the now combined gas of the two systems in a highly excited, heated, and turbulent state. The equatorial planes of the two systems seem to form an angle of about 20°. The total duration of the collision then is of the order of a million years.

R. Minkowski
Mount Wilson and Palomar Observatories

Transmission of Activity in the Mammalian Cortex

The usual concept of the activity of the cortex is that impulses travel along nerve fibers and over synapses from one nerve cell to another and that such guided impulses underlie the function of the cortex. The spontaneous electric activity of the cortex, shown by the electroencephalogram would represent a statistical outcome of such activity. There is an alternative concept of transmission where the electric fields of an active group of nerve cells can spread out to modify or excite other groups, and this is thought of as operating in addition to direct connectivity.

If the cortex is directly stimulated by a brief electric pulse, it gives rise to a characteristic electric discharge. This seems to be a forcing of a large number of

cells into combined activity, and this response can spread up to a centimeter or more in the rabbit cortex. When a cut is made through the cortex and the underlying white tracts connecting one area with another, the transmission of this response is blocked, except for a small potential on the opposite side. This remaining potential is roughly one-tenth the size of a regular response on the stimulated side, and the question arises whether this represents only a physical spread of current from the active side across the cut or whether it is a weak response of the cells to these electric fields. That the small potential is not such a response was shown by the failure of the excitant drug strychnine to enhance it or of spreading depression to block it.

Spreading depression is a phenomenon released by a more powerful distant cortical stimulation, which results in a wave of depression moving slowly through the cortex and blocking all activity—electroencephalographic and the cortical response. On the stimulated side of the cut, spreading depression blocks the response. On the opposite side, the small response remains. It is concluded that the small potential on the distant side of the cut represents a physical spread of activity and that this electric field is not sufficient to excite neuronal activity across the distance of a thin cut.

SIDNEY OCHS
California Institute of Technology

Theoretical Calculation of Gas Emissivities

Few experimental data are available for the total equilibrium radiant energy emitted from heated gases at moderate and elevated pressures. Although the theoretical calculation of gas emissivity has been understood since the development of the quantum theory of radiation, at least in principle, no serious efforts to determine this quantity from fundamental physical constants were published until a few years ago. The molecular parameters required at moderate temperatures (up to about 3000°K) are (i) integrated intensities for vibration-rotation bands, (ii) spectral line shapes and half-widths as functions of temperature and pressure, and (iii) adequate theoretical descriptions for relative intensities of spectral lines (within a given vibration-rotation band) and of entire vibration-rotation bands.

As the result of new experimental measurements and refinement of fundamental theoretical studies, as well as of the development of new evaluation procedures, it has become possible in practice to calculate gas emissivities. Successful computations, which are in agreement with engineering measurements of total emissivities where these are available, have been carried out for diatomic molecules and for CO_2 at moderate temperatures.

This work was supported by the Office of Naval Research under contract Nonr-220(03), NR 015 401.

S. S. PENNER
California Institute of Technology

Incorporation of the Pyrimidine Ring of Adenine into the Isoalloxazine Ring of Riboflavin

Uniformly labeled C^{14}-adenine has been administered to cultures of *E. ashbyii*. The C^{14}-riboflavin has been isolated, degraded, and shown to have 94 percent of the C^{14} limited to the pyrimidine ring of riboflavin.

The specific activities of the individual carbon atoms of the pyrimidine ring of riboflavin were quite closely related, from which it has been concluded that adenine serves as a precursor in the biogenesis of riboflavin through the contribution of an intact pyrimidine ring.

WALTER S. MCNUTT, JR.
California Institute of Technology

"Reward" from Brain Stimulation in the Rat

The present work started with the observation that a rat with electrodes chronically implanted in the anterior-commissure region would return to the place in an open field where electric stimulation had been applied. The animal appeared either to be curious about the stimulus or to be attempting to get more. Acting on the latter possibility, a situation was arranged in which the animal could stimulate its own brain by pressing a bar.

Under these conditions, the animal did in fact stimulate itself regularly for long periods of time, and such stimulation is inferred to be rewarding. By implanting in a number of brain areas, it was found that most electrodes in the septal area, lateral amygdala, and anterior hypothalamus produce extreme reward. Most electrodes in the cingulate cortex and hippocampus produce mild reward. Other electrodes did not produce reward.

To find whether this cerebral "reward" would function in a way comparable to conventional rewards in less stereotyped situations, learning and performance have been tested in a runway and maze, with electric stimulation as the only incentive. When electrodes were placed in the basomedial forebrain, in the area of the nucleus of the diagonal band and the olfactory tubercle, animals ran the runway faster for stimulation than for food and produced learning curves in the maze comparable to those of a control group running for food.

JAMES OLDS
McGill University and
University of California, Los Angeles

Photoproduction of Neutral Pions from Protons at Forward Pion Angles

Low-energy recoil protons from the process $\gamma + p \rightarrow p + \pi^\circ$, detected by nuclear emulsions placed within the hydrogen gas target container, have been used to measure the differential cross section. The entering angle and range of protons stopping in a tilted C-2 600-μ emulsion are measured, and from these data the incident photon energy and pion angle can be determined. In this manner protons of energies as low as 5 Mev can be detected at laboratory angles corresponding to emission of a pion at center-of-mass angles as low as 26°.

This experiment thus supplements that of R. L. Walker and D. C. Oakley [*Phys. Rev.* **97**, 1283 (1955)] which covers the same range of photon energies (200 to 500 Mev) but is restricted to pion angles greater than about 70°, owing to higher minimum detectable proton energy. Common experimental points provide intercomparison of absolute values. The data at lower photon energies may also be compared with the results of the M.I.T. [Goldschmidt-Clermont, Osborne, and Scott, *Phys. Rev.* **97**, 188 (1955)] and Illinois [L. J. Koester, *Phys. Rev.* **98**, 211 (L) (1955)] groups. The effect of the present results on the angular distributions and total cross sections deduced from previous data is presented and discussed. In particular, the measurement in the forward hemisphere provides a sensitive check on the value of B in the angular distribution $A + B\cos\theta + C\cos^2\theta$.

This research was supported by the U.S. Atomic Energy Commission.

VINCENT PETERSON
W. S. MCDONALD
California Institute of Technology
DALE R. CORSON
Cornell University

Double Crossing Over in Neurospora

It is known that a crossover involves exchange of material between only two of the four products of a meiosis. A knowledge of the strand relationships in multiple crossovers should be helpful in understanding the mechanics of the crossing-over process.

An ascospore mutant of *Neurospora crassa* has been used in this study. Crossing over in the region between the spore mutant locus and the centromere can be detected by the pattern of segregation for the spore character in the ascus. This feature makes it possible to avoid the labor of dissection and classification of those asci with no crossover in this region. Unfortunately, the spore mutant is nearly always lethal, so the two spore pairs in an ascus that carry it cannot be classified for other segregating mutants. This limits the amount of information obtainable, but it is still possible to detect the strand relationships of double crossovers in certain situations. In a study involving the interval from the ascospore mutant to the centromere (region A) and a marked region in the opposite arm of the same chromosome (region B), the two-strand and four-strand double crossovers and one of the two types of three-strand doubles are all detectably different from one another and from exchanges of lower rank.

Among 2928 asci there were 43 two-strand double crossovers, 54 of the detectable three-strand type, and 53 involving all four strands. This is consistent with the 1 : 1 : 1 ratio expected with random association of strands. One hundred ninety-eight asci with no crossing over in region

A gave a map distance of 16.7 units for region B. Among 610 asci with single crossovers in region A, the exchange rate in region B was 16.6 map units.

These results indicate that crossing-over events in one arm of a tetrad have no correlation with or influence on such events in the opposite arm. They fail to confirm the observation of Lindegren and Lindegren [*J. Heredity* 28, 105 (1937)] of a high coincidence of exchanges in the two chromosome arms with most of the double crossovers involving only two strands. The present findings are in good agreement with the recent study of Howe [*Records of the Genetics Society* (1954)], which showed no evidence of interference across the centromere.

DAVID R. STADLER
California Institute of Technology

Monthly Change of Diurnal Variation of Irregular Geomagnetic Fluctuations

A study of the diurnal variation of the irregular geomagnetic fluctuations in moderately low latitudes reported earlier [Nicholson and Wulf, *Science* **121**, 626 (1955)] for the 7 years 1940–46 has been extended to the 9 years 1940–48. The eight daily K numbers (3-hour-range indices) for six observatories (see reference) fairly well distributed in longitude have been used in this work. An average local-time and an average universal-time diurnal variation have been formally obtained from these data.

The monthly change of the local-time diurnal variation seems to be due largely to an afternoon subsidiary maximum occurring principally around the June solstice. The monthly change of the universal-time diurnal variation suggests roughly opposite character of the variation about the equinoxes. There is, however, an appreciable yearly average variation. When this is deducted from the monthly values, the averages of these departures for the 4 months around the December solstice and around the June solstice are nearly mirror images of one another.

SETH B. NICHOLSON
Mount Wilson and Palomar Observatories
OLIVER R. WULF
U.S. Weather Bureau,
California Institute of Technology

Determination of Crustal Structure from Local Variations of Phase Velocity of Rayleigh Waves

A method of deducing local changes in crustal structure from variations of phase velocity of Rayleigh waves is described. The method utilizes the prolonged, sinusoidal trains of dispersive Rayleigh waves characteristic of long oceanic propagation paths. Crests and troughs of these waves may be followed across a triangular array of seismograph stations when the station separations are not more than a few wavelengths. Phase velocity and direction of approach may be determined as a function of period.

Preliminary results for Southern California indicate a reduction of phase velocity of about 10 percent for waves crossing the Sierra Nevada range. This may be interpreted as an effect of crustal thickening under the mountains to depths about 50 percent greater than under the coastal regions.

FRANK PRESS
Seismological Laboratory,
California Institute of Technology

The Born Approximation in Electron Diffraction

The electron diffraction study of the geometric structures of gas molecules is productive and comparatively simple, partly because a simple theory—the Born approximation—is available for interpreting the complex physical phenomenon. Many hundreds of structures have been studied by the method. However, a few dubious unsymmetrical structures were reported, and the essential experimental results were later confirmed, all for molecules made up of both light and heavy atoms and most notably for uranium hexafluoride. It has now been recognized that a characteristic failure of the Born approximation is involved, and progress has been made toward a more adequate theory [V. Schomaker and R. Glauber, *Nature* **170**, 90 (1952); R. Glauber and V. Schomaker, *Phys. Rev.* **89**, 667 (1953); J. A. Hoerni and J. A. Ibers, *Phys. Rev.* **91**, 1182 (1953); J. A. Ibers and J. A. Hoerni, *Acta Cryst.* **7**, 405 (1954)]. The present status of the work is reviewed.

VERNER SCHOMAKER
California Institute of Technology

Individual Variations of Productivity in Research Laboratories

The contribution that an individual makes to science is almost impossible to evaluate quantitatively, and no attempt is made to do so in this study.

Significant indications of variations in productivity between similar groups of individuals can be studied statistically, using rate of scientific publication as a measure of one aspect of scientific productivity. (Previous investigations have shown correlation between amount of publication and other indices of scientific productivity.) Within a particular research laboratory—for example, Brookhaven, Los Alamos, or the National Bureau of Standards—there are scientists who publish 100 times more prolifically than others; the statistics of these variations may be described by a relatively simple distribution law, which states that the logarithm of the rate of publication is distributed normally.

The relationship between salary and productivity has been investigated in such a way as to eliminate the general increase in salary with age by using four salary quartiles, each having the same age distribution, average salary increasing in three steps from quartile IV to quartile I. Although there are large variations of rate of publication within each quartile, the average rate increases steadily, with quartile I being 3 to 10 times higher than quartile IV. A 30-percent to 50-percent increase in productivity corresponds to a 10-percent increase in salary, thus statistically much more output per dollar is obtained from the higher paid workers.

Generally, similar conclusions are reached by using either patent applications instead of publications or academic rank instead of salary. If it is assumed that, in addition to rate of publication, salary is determined by several other unknown, independent, and equally important factors, then the data can be best fitted by assuming that four factors altogether are involved.

WILLIAM SHOCKLEY
Bell Telephone Laboratories
Murray Hill, New Jersey

Maximum Information Rate through a Human Channel in Reading

The matter of the limiting rate at which a person can utilize or produce information arises in connection with communication and control systems of which a human being forms a part. Licklider, Stevens, and Hayes at M.I.T., and Quastler and Wulff at the University of Illinois have found information rates for reading aloud lists of randomized words, for pointing, for reading and pointing, and for playing random music.

The present work explores reading aloud. The limitation in reading rate is not mechanical, for a person can repeat phrases or read prose considerably faster that he can read randomized word lists. Reading rate is strongly governed by familiarity; two-syllable familiar words are read faster than one-syllable unfamiliar words. The rate is initially constant as the number of alternative words is increased. The maximum rate achieved, with a set of 2500 familiar one-syllable words, was 40 bits a second (220 words a minute). This is as high as reported by Licklider *et al.* for reading and pointing. Estimates for information rate in reading prose are somewhat below this, although word rates may be more than 300 words per minute. Very high word rates reported for silent reading are presumably rates for skimming, not reading.

J. R. PIERCE
J. E. KARLIN
Bell Telephone Laboratories,
Murray Hill, New Jersey

Crystallization of Purified MEF-1 Polio Virus

Highly purified and concentrated MEF-1 polio virus was prepared from infected monkey kidney tissue culture fluid by chemical and physical procedures, the final steps of which included fractionation by electrophoresis and by sedimentation in a sucrose density gradient. The product was a single homogeneous component con-

sisting of spherical particles 27 mμ in diameter with which infectivity has been shown to be associated. Three-dimensional crystals of the virus particles formed during 24 hours at 4°C in an ultracentrifuged pellet of the purified virus concentrate covered with unbuffered isotonic saline at *p*H 5.9. They appeared to be bipyramidal tetragonal prisms and were approximately 30 μ long. Ultraviolet microscopy of the crystals gave a spectrum consistent with that of a nucleoprotein—that is, absorption below 295 mμ and no absorption above 300 mμ. The washed crystals were readily dissolved and the virus was recrystallized from buffered saline.

Specific infectivity measurements (expressed as plaque-forming units per milliliter of virus suspension of one optical density unit at 260 mμ) of the original purified virus concentrate and of the dissolved crystals and mother liquors from the first and second crystallizations were the same. The results indicate that the crystals were composed of polio virus particles. Although several plant viruses have been crystallized, the present work represents the first time an animal or human virus has been obtained in the form of crystals observable by light microscopy.

C. E. SCHWERDT
F. L. SCHAFFER
University of California, Berkeley

Volume Changes on Mixing Nonpolar Liquids

According to the theory of "regular" solutions, two nonpolar liquids will expand on mixing, and the volume change observed should be proportional to the (positive) excess free energy usually observed for such systems. Newer approaches (Prigogine and coworkers, Salsburg and Kirkwood), based on the theory of corresponding states, predict, instead, contraction when two molecular species of nearly identical intrinsic size are mixed, even though the excess free energy is still positive.

Recently I have developed a new corresponding-states treatment of solutions that uses the experimentally observed equation of state of a reference liquid rather than the rather unrealistic theoretical models for liquids used by previous workers. When carbon tetrachloride is used as this reference liquid, one obtains equations:

$$\Delta F^E = \langle \Delta E^V \rangle [0.95(\eta^*)^2 + 1.67(\eta^*\xi^*) + 3.73(\xi^*)^2] x_1 x_2$$

$$\Delta V^M = \langle V \rangle [-0.03(\eta^*)^2 + 2.84(\eta^*\xi^*) + 3.27(\xi^*)^2] x_1 x_2$$

where $\langle \Delta E^V \rangle$ is the average energy of vaporization for the two liquids and $\langle V \rangle$ is the average of their molar volumes. The parameter η^* is proportional to the difference in the energies of vaporization; ξ^*, to the difference in volumes. Experimental measurements on solutions of nonpolar nonelectrolytes are in good qualitative agreement with these equations, although there are some notable exceptions.

The reason for the failure of the early theories of volume change lies in their assumption that the entropy of mixing at constant volume is ideal. Two liquids with different energies of vaporization are necessarily at different reduced temperatures and consequently unequal degrees of expansion; the resulting solution is in an intermediate state, and small but significant entropy deviations result.

ROBERT L. SCOTT
University of California, Los Angeles

Unidirectional Progression of Faulting

An epicenter determined from seismograms represents the initial point of a rupture, which in a large earthquake may extend for many miles. In several well-observed instances, instrumental epicenters for foreshocks, main shock, and aftershocks can be correlated with field observation of the extent of faulting. Rupture is found to begin at one end of the active fault segment. Aftershocks scatter along this segment but show concentration near the two ends. Foreshocks occur close to the main shock epicenter, possibly outside the segment of principal rupture. Many less completely known major seismic events can be assigned to the same pattern.

In a few large earthquakes faulting may have extended in opposite directions from the initial point. The common erroneous impression that this is the rule (instead of the exception) is due to the obsolete practice of locating epicenters on a noninstrumental basis, at the center of figure of the isoseismals representing local intensities. The instrumentally determined epicenter is normally to one side of this center of figure. This is to be expected if energy is radiated strongly from the central part of the fault segment; also, since radiation is in effect from a moving source, there are increased amplitudes in the direction toward which the rupture progresses.

C. F. RICHTER
Seismological Laboratory,
California Institute of Technology

Feasibility of High-Energy Photo-Meson Production Studies Using a Hydrogen Bubble Chamber

The feasibility and desirability of studying high-energy particle interactions using bubble chambers [D. A. Glaser, *Phys. Rev.* **97**, 474 (1955)], and in particular liquid hydrogen bubble chambers, have been well established [H. C. Dittler and T. F. Gerecke, UCRL Rpt. 2985 (1955)]. However, it is not obvious that such equipment may be successfully employed in a bremsstrahlung photon beam for photoproduction studies of π or K mesons, because of the relatively high background production from Compton scattering and pair production in the chamber.

With the generous assistance and cooperation of Luis Alverez, J. D. Gow, and the University of California Radiation Laboratory bubble-chamber group, and of Robert Kenney of the UCRL synchrotron laboratory, a feasibility study was made on the use of a hydrogen bubble chamber in such experiments. The UCRL 4-in. liquid hydrogen chamber was irradiated with 290 Mev photons from the UCRL electron synchrotron. Photographs were taken under varying beam conditions, both with and without the presence of a LiH beam "hardener" to absorb selectively low-energy photons in front of the chamber.

As was expected from preliminary calculations, it would appear impractical to perform meson production experiments with "unhardened" beams. However, with the background reduction resulting from the use of LiH, photo-production experiments involving total cross sections of 0.1 mb., and with improvements in technology considerably smaller cross sections would seem possible. Pi meson production experiments near threshold would appear to be very feasible, provided that the hydrogen temperature is maintained at a reduced value so that tracks of minimum ionization are "biased out."

JOHN M. TEEM
California Institute of Technology

Investigation of Nuclear Size by X-ray Fine-Structure Splitting in Heavy Atoms

Schawlow and Townes have shown that the L_{II}–L_{III} x-ray level separation in heavy nuclei is affected to a slight extent by the finite extension of the nuclear charge distribution. This influence, their theory shows, increases rapidly in the high atomic number range depending exponentially on Z, the atomic number. Schawlow and Townes have shown on the basis of presently available x-ray data fairly clear-cut evidence for the existence of the effect. Even for plutonium, however, the effect is so small that extreme accuracy in the x-ray measurements is required if one is to improve on existing data sufficiently to get information on nuclear charge distribution comparable to that available by such methods as the high-energy electron scattering of Hofstadter and associates at Stanford or the mesonic x-ray data obtained at Columbia, Rochester, or Pittsburgh. Since the different methods disagree somewhat regarding the sizes of nuclear charge distributions, considerable interest attaches to the problem. The present paper describes x-ray measurements directed at obtaining more accurate data for this specific purpose.

This research was sponsored by the U.S. Atomic Energy Commission.

ROBERT L. SHACKLETT*
JESSE W. M. DUMOND
California Institute of Technology
* Present address: *Fresno State College*

Diameter of the Andromeda Nebula

In 1933 Stebbins and Whitford measured the Andromeda Nebula with a photoelectric cell on the 100-in. telescope at Mount Wilson and traced the light of the nebula outward considerably beyond the limits shown on photographs, proving that

the nebula was at least twice as wide as had been previously assumed. The present report deals with recent similar work with the 36-in. Crossley reflector of the Lick Observatory. Improvements of 20 years, including the introduction of an RCA antimony-cesium photomultiplier in place of the former Kunz potassium cell and the substitution of a recording potentiometer for a visually read galvanometer, have made the sensitivity of the installation on the Crossley even better than that used on the 100-in. with its eightfold greater light-gathering power. For instance, the light and color of one or two of the brightest globular clusters in Andromeda were measured with difficulty with the 100-in., but recently Kron and Mayall have observed several score of these objects with the Crossley, most of them fainter than the former limit of the 100-in.

A series of continuous traces across the nebula, giving its intensity freed from the foreground of galactic stars, confirms the dimensions previously found, and the new study is being made in two or more colors. Each expansion of the measured dimensions of the nebula makes it a system more nearly comparable in size with our own galaxy.

JOEL STEBBINS
GERALD E. KRON
Lick Observatory

Energy Loss of Protons in Metals

The rate at which protons lose energy in passing through thin evaporated layers of metal has been measured for protons in the energy range between 50 and 600 kev. The materials studied are Li, Be, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Au, and Pb. Together with earlier measurements in this laboratory of the rate of energy loss in several gases, these results provide information about the variation of energy loss with the atomic number of the stopping material.

For high-energy protons, the energy loss per stopping atom increases smoothly with Z; the scattered results that are available are consistent with the theoretical $Z^{1/3}$ dependence. For protons of low energy, below 100 kev, marked departures from this dependence were observed in this experiment; for example, the stopping cross section of argon is greater than that of gold for $E_p < 100$ kev. The influence of molecular binding on the stopping cross section of compounds becomes noticeable below 150 kev. For protons of 500 kev, a fairly uniform Z dependence is apparent over most of the periodic table, but two types of deviation are still observed. First, the stopping cross sections of the noble gases are relatively lower than those of their neighbors. This effect can be understood in terms of the reduced energy loss to the more tightly bound electrons of closed shells. Second, in the region from $Z = 23 - 29$, the stopping cross section decreases with increasing Z. With the exception of a high value at Cr, the decrease is fairly uniform from V through Cu. Although stopping cross-section measurements are not available for the rare earths, the values for Xe and Au indicate that a similar decrease may occur in this region.

This research was assisted by the joint program of the U.S. Office of Naval Research and the Atomic Energy Commission.

WARD WHALING
R. E. PIXLEY
California Institute of Technology

Dislocations and the Yield Point in Steel

The theory of dislocations in metal crystals is employed to describe the mechanism of the initiation of plastic yielding in low-carbon steel. Dislocations are generated at Frank-Read sources when stress is applied to the material. The rate of generation is governed by the thermally activated release of the source dislocation from a Cottrell "atmosphere" of carbon and nitrogen atoms.

The first dislocation generated at a given source expands rapidly outward until it is stopped by the grain boundary. Succeeding dislocations come to rest at equilibrium positions in the slip plane between the source and grain boundary. The local shear stress at the grain boundary increases in proportion to the number of dislocations. When a critical value of this stress is reached, slip propagates across the boundary into adjacent grains, thus initiating the abrupt and discontinuous yielding that is characteristic of low-carbon steel.

Experimental observations of the time and temperature dependence of the initiation of yielding are correlated with the dislocation mechanism described. These observations include the delay time for the initiation of yielding under constant applied stress and the preyield microstrains that take place during the "delay time."

DAVID S. WOOD
California Institute of Technology

Inhibition of Cell Division in Sea Urchin Eggs by Specific Antiserums

Rabbits were immunized with various constituents of eggs and sperm of sea urchins, and the antiserums were studied for specific effects on development of the eggs. During these investigations it was observed that certain antiserums blocked cleavage of the eggs very effectively. Nuclear, as well as cytoplasmic, division was inhibited. The time for mitotic block in strong antiserums was less than the period of one division. Antiserums against extracts of unfertilized, as well as of fertilized, eggs were effective, but those prepared against whole sperm or specific extracts (for example, antifertilizin) thereof were not. Absorption with sperm did not remove the blocking action. Of special interest was the finding that antiserums prepared against purified fertilizin possessed the antimitotic action. Since fertilizin constitutes the gelatinous coat and surface of the unfertilized egg, and this is removed from the fertilized eggs on which the tests are made, the new surface is evidently antigenically related to fertilizin. The blocking action could be overcome by treating the antiserums with an excess of fertilizin.

A marked temporary rise in respiratory rate occurs in fertilized eggs treated with antimitotic antiserums. Determination of sodium content inside the treated eggs showed no significant increase. The tension at the surface of the egg increased greatly upon antiserum-treatment. Cytolysis occurs in the blocking antisera after several hours' exposure. Treatments as short as 15 to 30 minutes in strong antiserum suffice to block cell division irreversibly. Heating the antiserums at 56°C for 1 hour, to inactivate complement, does not destroy the antimitotic action.

ALBERT TYLER
JOHN W. BROOKBANK
California Institute of Technology

Substitution Reactions of Aromatic Halides

Previous research [J. D. Roberts *et al.*, *J. Am. Chem. Soc.* **75**, 3290 (1953); J. D. Roberts *et al.*, *ibid.*, in press] has demonstrated that the conversion of phenyl halides to aniline by potassium or sodium amide in liquid ammonia involves an elimination-addition mechanism probably by way of an electrically neutral entity of composition C_6H_4, "benzyne." It has now been found that mixtures of toluidines result from the amination of the individual halotoluene isomers. These mixtures have compositions that are at least consistent with operation of the elimination-addition mechanism and the expected electric effect of aromatic methyl groups.

A parallel study of rearrangements in high-temperature hydrolyses of halotoluenes has revealed that the extent of rearrangement is a rather sensitive function of temperature, alkali concentration, and the nature of the halogen. It is concluded that high-temperature hydrolyses of aryl halides may involve either elimination-addition or halide-ionization mechanisms, the latter being favored with the more easily ionizable halogens at low alkali concentrations. By suitable choice of conditions, one or the other reaction may be made to occur almost exclusively.

JOHN D. ROBERTS
A. T. BOTTINI
D. A. SEMENOW
California Institute of Technology

Problem of Beta Lyrae

Beta Lyrae is a naked-eye eclipsing double star, whose period of nearly 13 days has steadily increased since its discovery, at an average rate of the order of 9.4 sec/yr (Z. Kopal). This large increase must be due to a rapid evolutionary change in the binary system. This paper attempts to elucidate this change. A series of 195 high-dispersion spectrograms of Beta Lyrae obtained with the 100-in. telescope at Mount Wilson leads to a model for study. Both components of the

binary are unstable, presumably because they have individually grown in size, as a consequence of nuclear processes in their interiors, until they are now spilling over the critical surface of zero velocity, which is characterized by the common, inner Lagrangian point, L_1. Both supergiant components lose mass from their inner extremities, in the form of two violent currents or streams of gas, which gradually dissolve in a disk-shaped expanding nebulosity that ultimately escapes into interstellar space.

The effect of the streams is, as S. S. Huang has recently shown, to increase the period and the orbital radius. A rough estimate, by Huang, of the loss of mass required to produce the observed increase in the period is 3×10^{22} g/sec, if the mass of the B9 component is 52 $\odot$. The total area from which the two streams emerge is of the order of 10^{25} cm^2. Hence, each square centimeter ejects, theoretically, 10^{-3} g/sec, or 10^{21} atoms/sec, mostly of ionized hydrogen. At certain phases we observe the streams moving with a velocity of about 200 km/sec, through a depth of about 2×10^6 km. The entire amount of material producing a violet-displaced absorption line was, therefore, ejected in 10^4 sec. The resulting number of atoms in the entire stream is, thus, 10^{25} cm^2—an amount that is not inconsistent with the observed equivalent widths of the absorption lines, especially in view of the fact that the ionization of hydrogen in the stream must be very large.

The total mass of the heavier component (B9) of the Beta Lyrae may be about 50 times that of the sun or, roughly, 10^{35} g. Hence, at its present rate of dissipation it would exhaust most of its substance in 3×10^{12} sec, or 100,000 years.

OTTO STRUVE
JORGE SAHADE
University of California, Berkeley

Use of Multiple Spectrograph Slits in the Study of Internal Motions of Gaseous Nebulae

The bright planetary nebulae are all relatively small objects with diameters of the order of 10 to 20 sec of arc. Radial velocities of the nebular material may be obtained by placing the telescopic image of a nebula on the slit of a spectrograph and photographing the resulting spectrum.

A spectrograph with a single slit provides kinematic information only along the narrow strip of the nebula where the slit crosses the image. Since the exposure times are rather long, it would be time-consuming, as well as extremely difficult, to map accurately the kinematic relationships across a nebula by means of a series of single-slit exposures.

The problem is readily solved by using simultaneously a number of closely spaced parallel slits on which the nebular image is centered. In this manner it is possible, for the same expenditure of telescope time required for a single-slit exposure, to obtain a kinematic picture of the entire object.

Such multislits, ruled on an aluminized piece of glass, have been constructed for both the 100-in. and 200-in. telescopes and have provided much instructive data on the internal motions of the planetaries. At Palomar a multislit is currently being used to investigate the detailed internal motions of the Orion Nebula.

O. C. WILSON
Mount Wilson and Palomar Observatories

New Books

Handbook of Hydrocarbons. S. W. Ferris. Academic Press, New York, 1955. 324 pp. $8.50.

Handbuch der Pflanzen-Züchtung. Band 1, *Grundlagen der Züchtung*; Lieferung 1, *Biologisch-genetisch und Physiologische Grundlagen der Züchtung.* Hans Kappert and Wilhelm Rudorf, Eds. Paul Parey, Berlin, ed. 2, 1955 (to be published in 6 vols., comprising approximately 38 issues). 80 pp. DM. 13.50 per vol.

The Construction of Laboratory Apparatus for Schools. Workshop designs with specifications and instructions. Ser. II, *Secondary* (in French and English). Prepared for UNESCO by H. Struers Chemiske Laboratorium, Copenhagen, Denmark. UNESCO, Paris, 1955 (order from Columbia Univ. Press, New York). Portfolio and 76 plates. $8.

Genetics Notes. James F. Crow. Burgess, Minneapolis 15, ed. 2, 1955. 124 pp. $2.50.

Annual Review of Physical Chemistry. vol. 6. G. K. Rollefson, Ed. Annual Reviews, Stanford, Calif., 1955. 515 pp. $7.

The Physiology of Diapause in Arthropods. Cambridge Monogr. in Experimental Biology No. 4. A.D. Lees. Cambridge Univ. Press, New York, 1955. 151 pp. $2.50.

Erlebtes aus der Thoraxchirurgie. Rudolf Nissen. Thieme, Stuttgart, 1955 (Order from Intercontinental Medical Books, New York 16). 65 pp. $3.40.

Amateur Astronomer's Handbook. J. B. Sidgwick. Macmillan, New York, 1955. 580 pp. $12.50.

Advances in Cancer Research. vol. III. Jesse P. Greenstein and Alexander Haddow. Academic Press, New York, 1955. 369 pp. $8.50.

Cancer Cells. E. V. Cowdry. Saunders, Philadelphia, Pa., 1955. 677 pp. $16.

Gas Kinetics. An introduction to the kinetics of homogeneous gas reactions. A. F. Trotman-Dickenson. Academic Press, New York; Butterworths, London, 1955. 322 pp. $8.

Instruments for Measurement and Control. Werner G. Holzbock. Reinhold, New York; Chapman & Hall, London, 1955. 371 pp. $10.

Man's Nature and Nature's Man. The ecology of human communities. Lee R. Dice. Univ. of Michigan Press, Ann Arbor, 1955. 329 pp. $5.

Man's Emerging Mind. Man's progress through time—trees, ice, flood, atoms and the universe. N. J. Berrill. Dodd, Mead, New York, 1955. 308 pp. $4.

Miscellaneous Publications

(Inquiries concerning these publications should be addressed, not to Science, *but to the publisher or agency sponsoring the publication.)*

Natural Availability of Oak Wilt Inocula. Bulletin of the Illinois Natural History Survey, vol. 26, No. 3. E. A. Curl. 26 pp.

Joint FAO/WHO Expert Committee on Nutrition. Fourth report. WHO Tech. Rpt. Ser. No. 97. World Health Organization, Geneva, 1955 (Order from Columbia Univ. Press, International Documents Service, 2960 Broadway, New York 27). 58 pp. $0.60.

Oil and Gas Pipe Lines in Ohio. A map. Compiled by Robert L. Alkire. Ohio, Department of Natural Resources, Columbus, rev. ed., 1955. $1.50.

Some Polyclad Flatworms from Polynesia and Micronesia. Proceedings of the United States National Museum, vol. 105, No. 3352. Libbie H. Hyman. The Museum, Washington, 1955. 17 pp.

Geology of Olympic National Park. Wilbert R. Danner. Univ. of Washington Press, Seattle, 1955. 68 pp. $1.25.

Annual Report, 1954. Harvard Astronomical Observatory. The University, Cambridge, Mass., 1954. 42 pp.

Methods of Detecting and Tracing the Movement of Ground Water. Annual Progress Rpt. No. 1, Canal Seepage Research. Warren J. Kaufman and David K. Todd. Sanitary Engineering Research Lab., Univ. of California, Berkeley, 1955. 130 pp.

Summary of Survey of Philanthropic Foundation (Excerpted from *American Foundations and Their Fields,* 7th ed.). Wilmer Shields Rich. American Foundations Information Service, New York 3, 1955. 32 pp. Single copy free.

Science in Alaska, 1952. Proceedings of the Third Alaskan Science Conference, Alaska Division, AAAS, held at Mt. McKinley National Park, 22–27 Sept. 1952. Alaska Division, AAAS, College, Alaska, 1954. 221 pp. $3.

Report of the University Museums, 1953–1954. Univ. of Michigan, Ann Arbor, 1955. 28 pp.

Annual Report of the Dean, 1954. Harvard School of Public Health. Harvard Univ., Cambridge, Mass., 1955. 243 pp.

Toxicity to Greenhouse Roses from Paints Containing Mercury Fungicides. Bull. 595. A. E. Dimond and E. M. Stoddard. Connecticut Agricultural Experiment Sta., New Haven, 1955. 19 pp.

The C.S.I.R.O. Poultry Research Centre. Tech. Paper No. 1, Div. of Animal Health and Production. F. Skaller. 19 pp.

Common Names of Insects and Allied Forms Occurring in Australia. Bull. No. 275. Compiled under the direction of F. J. Gay. 32 pp. Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, 1955.

Baltimore and the H-Bomb. Vol. 9, No. 2. Studies in business and economics. Bur. of Business and Economic Research, Univ. of Maryland, College Park, 1955. 16 pp.

A Survey of Atomic Constants. J. A. Bearden and John S. Thomsen. Johns Hopkins Univ., Baltimore, Md., 1955. 138 pp.