SECTION ON PHYSICS

Chairman: S. E. Elliott, Butler University

All the papers listed in the program and published in full or in abstract form below were read. The attendance was good. Raymond B. Abbott, of Purdue University, was elected chairman of the section for 1939.

ABSTRACTS

Wave motion demonstration. S. E. Elliott, Butler University.—The machine is designed to aid high school and college students in getting a better understanding of both transverse and longitudinal waves. It shows two transverse waves, traveling in the same or in opposite directions, with the resultants back of them. These waves can have any relative amplitude and wave length, but, as constructed, they are equal in all respects and thus cause standing waves when traveling in opposite directions. The machine also shows a longitudinal wave in which the relative phase of successive particles can be changed, showing longitudinal waves of different length. With additional equipment, standing longitudinal waves can also be shown. All the waves can be made to travel as slowly as desired.

On the thermoelastic properties and on the equation of state of rubber. F. E. Dart and E. Guth, University of Notre Dame.—The high reversible elasticity and the anomalous thermoelastic behavior of rubber are explained qualitatively and to a large extent also quantitatively in terms of the molecular structure of rubber without making any arbitrary assumptions. Rubber consists of long chain molecules, which, in the unstretched state, are in a more or less curved form due to the possibility of free rotations around a single C-C bond in the single chains. This curved form is the most probable one according to the statistical interpretation of the second law of thermodynamics. If a stress be applied, these curved molecules will be stretched, thus giving a transition to a less probable state. When the stress is released, the thermal agitation causes a retraction. Rubber elasticity is then analogous to the elasticity of a gas or a liquid. In order to test and develop further this theory, experimental work on the physical properties of natural and synthetic rubber was begun. Our first objective was to obtain the thermal equation of state of rubber, i. e., the dependency of the stress upon temperature and extension. The thermal state equation together with the so-called caloric state equation, i. e., the dependency of the specific heat at constant extension upon the temperature and the extension, determines completely the thermodynamics of stretched rubber. It gives the free energy of stretched rubber. A

stress-strain apparatus allowing stretching and retracting rubber with a constant speed was used in some preliminary work with different types of rubber. Diagrams are presented which show the reproduceability of the data obtained and the change of the extension-retraction curves, i. e., of the hysteresis hoops, with the number of extensions and temperature. Diagrams for equations of state are shown. For elastically normal substances, e. g., steel, wood, etc., the stress decreases with rising temperature. This shows that in these cases the great elastic force between the atoms or molecules causes the retraction for rubber. This force-mechanism of elasticity is present also. However, in addition to the force-mechanism the statistical mechanism described above contributes to the retraction and can even predominate giving rise to an equation of state according to which the stress increases with rising temperature just as this is the case for a gas.

Proton diffraction by vapors. H. J. YEARIAN, Purdue University.—The methods of electron diffraction in molecular structure analysis are inapplicable to molecules of low molecular weight because of the low scattering power of such molecules. Since protons should be scattered much more strongly than electrons, extensive experiments have been made to investigate their diffraction by molecular vapors. It was found possible to obtain diffraction patterns of carbon tetrachloride but not of lighter molecules. The apparatus used, difficulties encountered, and principal results are discussed.

A fundamental error in wave motion. R. R. RAMSEY, Indiana University.—Since it has been shown that *damped wave* oscillators and *continuous wave* oscillators apparently do not give the same kind of resonance curves, detailed studies have been made of the modes of vibration. When the coupling is close, there are two possible modes of vibration, one stable and the other metastable. The circuit does not oscillate in these two modes at the same time. When the oscillator is started, it always assumes the stable mode; the metastable mode is secured by gradually changing the constants of the circuit. It is shown that a damped wave oscillator produces a band of frequencies, and, since a closely coupled circuit is in resonance for two peak responses, the circuit picks out the two frequencies. This is the reason why it was concluded in the old spark days that coupled circuits produce two frequencies. It is proved definitely that coupled circuits do not produce or manufacture two frequencies. This correction should be applied to modern physics.

Modulation a linear process. R. R. RAMSEY, Indiana University.—It seems to be the opinion of many that modulation is a non-linear process, but it is pointed out that, if the adjustments of the circuits are right, it is a linear process. In a class C amplifier, in which the radio frequency current is directly proportional to the plate potential, we have the products of sine terms, with side bands and no harmonics, when the amplifier is modulated. Modulation can also be produced by non-linear addition, but this always produces harmonics and other undesirable combinations.

The scattering of barytrons. J. F. CARLSON, Purdue University.—The increasing experimental evidence for the existence of a "heavy electron" gives importance to the theoretical calculations of its interaction with matter and radiation based on the various models which have been suggested. Since the explanation of nuclear forces by means of the barytron is best given by the description which uses a vector wave function, the calculations for this model are especially important. Only the elastic scattering will be considered. Elastic scattering may take place by two processes, (a) by the absorption and re-emission of barytrons by nuclear particles, analagous to the Compton scattering of light, (b) by the Coulomb field of a nucleus. The first process has been investigated by Heitler, and the second is considered here. The results show that for low energies the Coulomb scattering is more important than the first process and that for high energies the reverse is true. There are also polarization effects present in the scattering which may be of importance for particles traversing the atmosphere.

The Purdue cyclotron. W. J. HENDERSON, Purdue University.—Since the last report to the Indiana Academy of Science the construction of the Purdue cyclotron has been completed. This paper is a description of the construction of the accelerating chamber and of the adjustments of the magnetic field and oscillator. The magnetic field has been corrected by a special ring shim so that the field is now uniform over an area of 40 cm. in diameter. The oscillator and magnetic fields are tuned at present to produce 4.4 million volt protons, 8.8 million volt deuterons, or 17.6 million volt particles. Experiments are being conducted to adapt the low voltage arc as a source of ions.

On the interaction of high energy electrons with nuclei. EUGENE GUTH, University of Notre Dame.—Interaction of high energy electrons with nuclei can give rise to scattering, pair production, and disintegration phenomena. From the theoretical point of view, the pair production and radiation are equivalent processes. The cross-section for both phenomena can be obtained from the same expression by changing simply the variables. Whereas, the experimental results on radition of electrons above one million electron volts are in accordance with the theories at least in the order of magnitude, the experiments of pair production are contradictory with each other and with the theory also. Nuclei can be disintegrated by fast electrons provided that the energy of the electrons exceeds the binding energy of one of the constituents of the nucleus. The threshold value is only for the beryllium nucleus and the deuteron within the range of electron energies available at present experimentally. The cross-section for the disintegration of the beryllium nucleus was calculated by using both the method of Moller and that of the Fourier analysis. The threshold energy is according to the experiments with gamma rays on the photodisintegration of beryllium 1.7 MEV. This represents the lowest known threshold energy for any nucleus. The cross-section for the disintegration of Be_4^9 into Be_4^8 and a neutron is according to a very conservative estimate of the quantities entering into the formula 10^{-31} cm^2. This is

a thousand times smaller than the observed cross-section for the disintegration of beryllium with gamma rays. Experiments to detect an electroneutronic disintegration are in process using electrostatic generators. High energy electrons can also be used for the excitation of nuclei and for the sounding of the nucleus in analogy to the measurement of molecular distances by X-rays and low energy electrons.

On the preparation of metal surfaces for electron emission studies. EDWARD A. COOMES, University of Notre Dame.—The most important requirement imposed upon filaments used in electron emission studies is that they be absolutely gas-free as far as the surface is concerned. Two methods have been generally employed for obtaining clean surfaces. The first, commonly employed for highly refractory metals, consists simply in heating at high temperatures for long periods of time to rid the body of the filament of absorbed gases and a final high temperature flash to clean the surface of gases adsorbed to it. The second method, used mostly for metals of low melting point, consists in building up the working surface by evaporating onto a base filament from a source of the desired metal. Experimental data in general have shown both of these methods to be inadequate for quantitative studies. A further method is offered in which a working surface is built up on a well outgassed filament by evaporating, not from the supposedly pure metal but from a source containing the metal in chemical combination. It has been found, at least in the case of thorium, that such a source can be made to give off the pure metal and hold the gas apparently in solution in the body of the filament if the proper cycle is followed. This is confirmed by experimental work on secondary emission of electrons from a tungsten surface, coated with thorium evaporated from thoriated tungsten.

Continuous Spectra of H_2 and D_2. HUBERT M. JAMES, Purdue University.—Complete theoretical computations have been made of the continuous spectra of H_2 and D_2 arising from transitions from the lower vibrational levels of the $1s\sigma 2s\sigma\ ^3\Sigma_g$ state to the unstable $1s\sigma 2p\sigma\ ^3\Sigma_u$ state. Spectra have been determined for transitions from each of the vibrational levels separately, and the first reported computations on absolute mean lives of molecular vibrational levels have been made. Relative probabilities of excitation from the ground states of the molecules by electron impact have been estimated, and intensities in the spectra excited by electron impact have been computed for a range of energies of the electrons. The spectra of H_2 and D_2 have the same qualitative character but quite appreciable quantitative differences. In the case of H_2 there is sharp disagreement of the results with the observations of Smith. This apparently arises from errors in Smith's intensity standard and emphasizes the need of a more satisfactory intensity standard in the ultraviolet. Agreement with the observations of Finkelnberg and Weizel is obtained.

On the van der Waals energy of two beryllium atoms. JULIAN K. KNIPP, Purdue University.—The first term in the expansion of the electrostatic interaction of two neutral atoms in powers of $1/R$, where

R is the interatomic distance, is the term in $1/R^3$, the dipole-dipole term. Since isolated atoms have no dipole moments, the effect of this term on the energy of the system is only through the mutual polarization of the atoms, a second order effect first treated quantum mechanically by Wang. The constant u in the van der Waals energy, $-u/R^6$, has been calculated for two beryllium atoms using the Hartree-Fock model for the atoms. Perturbation methods are used based on the complete set of solutions of the Fock single-electron differential-integral equation. These solutions satisfy sum rules which, because of the integral part of the Fock equation, are not in general given by the usual relations. Lower bounds to the interaction expression are obtained by the application of the Schwarz inequality and the use of the sum rules derived. In this way u for two beryllium atoms is found to be about 222 10^{-60} erg cm^6.

The fashioning of perfect ellipsoidal boulders by glacial action. OLIVER E. GLENN, Lansdowne, Pa.—The general principles of the flow of a viscous stream, such as the lower layer of a glacier, are obtained by applying mathematics to some types of boulders which are shaped by the action of streams heavily charged with siliceous sand. In upper New England there have been found numerous granite boulders which are mathematically perfect ellipsoids, each with the principal axes different in length; and many of the hills of Maine are hyperboloids. From these facts the law of flow of the stream which fashioned the boulders is derived, appearing in a typical case as follows:

$$F = \text{Speed} = \frac{S\sqrt{(a^4 \sin^2\theta + b^4 \cos^2\theta)}}{b^2 \cos^3\theta}.$$

The speed at a given level is thus a function of θ with two parameters, S and a/b, and it may further be generalized to contain three parameters. (The origin of polar coördinates (r, θ) was taken as the center of the conicoid.) Reversing the problem and assuming the law of flow in the form F, the solution of a differential equation of the first order shows that the boulder will be an ellipsoid or hyperboloid. This principle offers an explanation why the Tipton Till Plain is flat while the New England landscape is hilly, as well as a number of other suggestions of possible interest to geologists.

Application of trigonometric interpolation to X-ray analysis. C. LANCZOS and G. C. DANIELSON, Purdue University.—The integral representing the intensity distribution of X-ray diffraction in liquids can be evaluated by the method of trigonometric interpolation instead of approximating the integral by the sum of a large number of terms. This reduces considerably the number of ordinates required in the calculation without decreasing the accuracy. As an example, the diffraction patterns of vitreous selenium and liquid KCL and LiCl, obtained and analyzed by K. Lark-Horovitz and E. P. Miller, have been interpreted. For the curves so far analyzed, 36 ordinates were found to be sufficient. Owing to symmetry properties the Fourier coefficients can be found with a minimum of calculation. This yields directly the value of the distribution function in discrete equidistant points. The

value of the function for any intermediate point may then be determined in a simple manner by pure calculation. The resulting curves agree very closely with those obtained by Lark-Horovitz and Miller.

The resonance processes in the disintegration of Boron by protons. BERNARD WALDMAN, University of Notre Dame.—Using protons of energies from 150 kev to 195 kev, the gamma ray and alpha particle yields from a thick boron target were determined simultaneously. The observed resonances occur at the same voltage, to within 1 kev. Yield curves on the alpha particles alone place the resonance voltage at 165 $\pm$ 4 kev. The observed half-breadth of 6 kev can be ascribed to energy fluctuations in the ion beam. The experiments were done at New York University in collaboration with R. Waddel, D. Callihan, and W. A. Schneider.

A device for demonstrating the resultant of two concurrent forces. C. O. PAULEY, Valparaiso H. S.—Demonstration of apparatus.

The trochoid method of magnetic focusing as applied to a study of pair production by electrons. ROBERT L. ANTHONY, University of Notre Dame.—Experimental values of the cross-section for pair production in the field of a nucleus by high speed electrons are in poor agreement at the present time. Skobelzyn and Stepanowa, using a cloud chamber, found a value for this cross-section about one hundred times larger than that for gamma rays of the same energy. Da Silva's work, also done with a cloud chamber, yields a value of 8×10^{-23} cm^2 for lead—about half as large as the value of Skobelzyn and Stepanowa. Benedetti, using the trochoid method of focusing and counters, and Alichanow and coworkers, using magnetic focusing and counters, decided that the value was much smaller, too small to be detected by their methods. Staub concluded the value could not be greater than that for gamma rays. Later, Monadjemi, using the trochoid method, obtained large values of the order of 10^{-23} cm^2. Recently work performed by Feather and Dunworth indicates that the larger experimental values may be correct. The majority of these experimental results are much higher than those predicted by theory and seem to indicate that the cross-section is proportional to Z and not to Z^2. In view of the disagreement between these experimental values, and since a large monochromatic source of high energy electrons is available at Notre Dame, we have decided to attempt a more accurate determination of this cross-section. For this purpose, the trochoid method of focusing will be used. This method is particularly well adapted to the problem since the yield obtained by it is from one hundred to a thousand times larger than that obtainable by ordinary magnetic focusing. The magnet which has been constructed for this purpose and the advantages of the trochoid method are described.