ducing such coordinates x, y, z, t, *and making use of the transformation equations for entropy, heat and temperature provided by the special theory of relativity,* we find, however, that our principle then reduces to

$$\left[\operatorname{div}(\phi\bar{u}) + \frac{\partial\phi}{\partial t}\right]\delta x\,\delta y\,\delta z\,\delta t \geqq \frac{\delta Q}{T} \qquad (21)$$

where ϕ, $\bar{u}$, δQ and T are now the quantities referred to our present coordinate system which we ordinarily designate as entropy density, velocity, heat absorbed and temperature. And we see that this result does relate the change in the entropy of the element of fluid, instantaneously contained in the coordinate range $\delta x\ \delta y\ \delta z$, to the absorbed heat and temperature in the way

$$\frac{d}{dt}(\phi\,\delta x\,\delta y\,\delta z)\,\delta t \geqq \frac{\delta Q}{T} \qquad (22)$$

which is required by the second law of thermodynamics in special relativity.

At the present stage of observational knowledge, our belief in the validity of the proposed postulate is primarily based on this agreement with the two principles of covariance and equivalence. In addition, however, it may be emphasized that the principle has been chosen so as to be simply the immediate covariant re-expression of the special relativity form of the second law (21); and past experience has shown, notably, for example, in the cases of the fundamental formulae for space-time interval and geodesic trajectory, that these simplest possible covariant generalizations when feasible are likely to be correct. Furthermore, it may be remarked that the conclusions which have so far been drawn from this extension of thermodynamics to general relativity appear—at least after due reflection—to be reasonable and illuminating.

It must be emphasized, nevertheless, that these qualities are not sufficient to prove the validity of the postulate, since other covariant expressions might be found which would also reduce to the special relativity law in natural coordinates. Hence the postulate must be regarded as a real generalization with a range of validity to be finally determined only by the correspondence between observation and prediction.

(To be concluded)

STUDIES IN NUCLEAR PHYSICS

By Dr. JNO. A. FLEMING

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STUDIES IN NUCLEAR PHYSICS

THE Carnegie Institution of Washington announced on February 2 in a lecture by Dr. M. A. Tuve before the Franklin Institute on "The Atomic Nucleus and High Voltages," the results of the past year's work at the high-voltage laboratory of its Department of Terrestrial Magnetism in Washington. This program of investigations constitutes the present expression of a long-continued policy of the department of undertaking laboratory studies of the basic physical phenomena which underlie all large-scale manifestations of magnetism and electricity, as complementary to its field and observatory operations and theoretical investigations. These laboratory studies are now directed toward studies of the simplest cases of the interaction at close distances of the known primary material particles—the electron and proton, which have both electric charge and magnetic moment—and their simplest combinations.

During the past year Dr. Tuve and his colleagues, L. R. Hafstad and O. Dahl, have obtained results covering a variety of experiments in nuclear physics, including a verification of the existence of the recently discovered neutron, observations on the resonance-disintegration of aluminum by polonium alpha-particles, and studies of the disintegration of lithium and boron, using high-speed protons from a high-voltage tube. The Van de Graaff type of electrostatic generator, a simple metal sphere charged to a high voltage by a silk belt, was tested, developed and used for the atomic disintegration-studies. A special building is now under construction at the department to house a large (2-meter) generator of this type which was built at the department and tested during May, 1932. This equipment promises to give an intense source of artificial neutrons, this being one of the most interesting of its numerous potentialities. It will provide 10 microamperes or more of protons or helium-ions having energies above 1,500,000 electron-volts.

The existence of the non-classical phenomena at present explained on the neutron-hypothesis was verified in the department's laboratory last September by a repetition of the main features of Chadwick's experiments. Using a 3-mc polonium source bombarding beryllium, recoil-nuclei of nitrogen were found to produce a maximum of nearly 50,000 ions in the 15-mm ionization-chamber of a valve-counter of the type used by Chadwick. Recoil-nuclei were observed with this instrument and with the FP-54 pliotron connected to a small chamber and used in the same way as Pose has used the duant electrometer. The

range of the recoil-protons was found to be about 44 cm in agreement with Chadwick's result. Several thousand stereoscopic photographs were made with the neutron-source mounted in a Wilson cloud-chamber, as in Feather's experiments, and the recoil-nuclei were identified and measured. Disintegration-phenomena in the chamber were not definitely assigned to neutrons because of the weakness of the source, but will be studied shortly using a much larger quantity of polonium. The absorption of the beryllium neutrons by one inch of lead, measured by counts of recoil-protons, was found to be about 55 per cent., in disagreement with Chadwick's 13 per cent. (measured by nitrogen-recoils), but agreeing with the value published in October by Thibaud and La Tour.

As a necessary safeguard to the validity of results with the high-voltage technique, as well as by reason of their intrinsic value, it was decided two years ago to carry out certain experiments using radioactive sources. One feature of this program was the development and test of instruments and methods for nuclear observations. The limits of sensitivity of the FP-54 pliotron have been investigated, and it has been utilized for measurements on high-speed protons produced by disintegrations and by neutron-recoil. A single-tube circuit using an FP-54 in an evacuated case achieves a charge-sensitivity limited only by the statistical fluctuation ($\pm$ 640 e) of the grid-current (10^{-15} ampere) of the tube, and the latter imposes a usable limit with this device not inherent in a true electrometer, although the much higher voltage-sensitivity is an advantage in many applications. Because of this fluctuation the minimum steady current theoretically observable is approximately 3×10^{-19} ampere (2 electrons per second), and by actual test a current of 5×10^{-18} ampere (30 electrons per second) is directly measurable in a time of several minutes. On the basis of experience with a cloud-chamber similar to that described by Blackett, an improved form was constructed, which has several important advantages over the usual form utilizing a piston and a liquid seal. A large-diameter flexible metal "sylphon" bellows is used, giving a chamber entirely free from leakage, with resulting constancy of expansion ratio and gas composition, which can be oriented vertically or in any other direction at will. A modified form of mercury spark-lamp provides sufficient illumination to enable the use of cinema positive film, with a very considerable gain in resolving power and contrast over the usual negative emulsion. A valve-counter of the type described by Wynn-Williams and Ward was developed, which is simple in construction and singularly insensitive to external disturbances, operating satisfactorily in the presence of the noise and electrical disturbances produced by the Van de Graaff generator. The useful amplification of such a device being limited solely by the noise-level of the early stages, this factor was investigated. The resulting amplifier has a noise-level comparable to the theoretical noise-level due to the Johnson effect (thermal agitation of electrons in a resistance) of the plate-impedance of the input-valve.

One problem of importance in radioactive research which was selected for attack is that of resonance-disintegration of the nucleus. Using the FP-54 in the same way as Pose has used the duant electrometer, Mr. Hafstad has studied the resonance-disintegration of aluminium. This work is only partially completed, but has progressed to a point where there can be no doubt of the existence of the phenomenon. Steudel's failure to observe it is not surprising in view of the geometry of his apparatus, and in contradiction to his results Mr. Hafstad finds that the "disintegration-yield" in his experiments, on the basis of an absolute calculation, checks Pose's high value. Details of the sharpness of resonance and other features are still under investigation.

Having experimented in this laboratory since 1926 with high voltages from spark-excited Tesla coils applied to vacuum-tubes, chiefly by reason of the lack of funds for a more suitable voltage-source, we were glad to adopt the inexpensive electrostatic type of generator for high voltages in air devised by Dr. R. J. Van de Graaff a year and a half ago. A generator of this type was built by the department a year ago, using a 2-meter aluminum sphere, charged by a 6-inch silk belt, and potentials as high as 2,000,000 volts were obtained in tests out-of-doors. Sufficient laboratory space not being available for immediate use of this generator, a 1-meter generator was assembled, and this has been used with a 23-section cascade-type vacuum-tube formerly used in the Tesla coil work. One interesting feature is the focusing action of such a tube, which approaches 100 per cent. for currents of 0.5 microampere of hydrogen- or helium-ions at 600 kv, although there is only a 2-cm diameter hole down the 5-foot tube. A hollow-anode, low-voltage arc (suggested by Dr. E. S. Lamar) is used for the ion-source, mounted inside the sphere and with the necessary power supplied by generators driven by the silk belt which charges the sphere. With this apparatus the disintegration of lithium and boron by high-speed protons has been investigated. With a very thin mica window on the tube near the target, the alpha-particles produced by the disintegrating nuclei have been identified and recorded by the linear amplifier (valve-counter) mentioned above. Lithium is found to give two ranges of alpha-particles in

approximately equal numbers, the shorter range being just under two centimeters. The disintegration-yield from boron is roughly twenty times that of lithium at 600 kilovolts, and the majority of these alpha-particles have a range of nearly 3 cm, with a much smaller number having a longer range. Preliminary measurements indicate that for boron about 4,000,000 protons are required to produce one disintegration at 600 kilovolts. These results are in approximate agreement, both as to ranges and disintegration-yields, with those recently reported in *Nature* by Cockroft and Walton.

Dr. Tuve's lecture will be published in the *Journal of the Franklin Institute.*

OBITUARY

TIMOTHY E. WILCOX

BRIGADIER-GENERAL TIMOTHY E. WILCOX, retired Army surgeon, living in Washington, D. C., died on December 10, at the age of ninety-two years. He was born at North Litchfield, New York, on April 26, 1840. He graduated from Union College in 1861 with an A.B. and received the A.M. degree in course.

A brief tour with McClellan's army ended with typhoid fever. His medical studies were resumed and he received M.D. from the Albany Medical College in 1864. He was immediately appointed assistant surgeon of the 6th New York Heavy Artillery. He attended Jefferson Davis during his detention at Fortress Monroe after the Civil War. He was appointed assistant surgeon in the regular army in May, 1867, retiring as brigadier-general in April, 1904. In November, 1898, he went to Cuba as lieutenant-colonel chief surgeon and was honorably discharged in May, 1899.

General Wilcox was a born naturalist. Everything was fish to his net—plants, animals, minerals, insects, worms, reptiles, fossils, etc. The National Museum and other museums received many rare specimens from him. The fossil horns of a tiny deer and those of a primeval ox are in the National Museum. The snake *Tontilla Wilcoxii* Stejneger was from Arizona. *Townsendia Wilcoxiana* Wood was discovered at Camp Supply, Indian Territory, in the seventies. *Primula Wilcoxii* Wood (?) was from Fort Boise, Idaho. *Panicum Wilcoxianum* Vasey was collected in Nebraska, *Quercus Wilcoxii* Rydberg and a cactus from Fort Huachuca, Arizona. His article in *Nature* in 1879–80 calling attention to the absence of angle worms around Boise, Idaho, caused much comment. He was author of occasional notes and papers in medical and other journals. From 1917 he was nearly blind, but his mind was clear to the end.

General Wilcox belonged to Phi Beta Kappa, Alpha Delta Phi, the Cosmos Club, Biological Society of Washington and the National Geographic Society. He joined the Torrey Botanical Club in 1880, being proposed by Dr. Alphonso Wood. In 1930, after 50 years membership, he was made a life member of the club.

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BUREAU OF PLANT INDUSTRY
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RECENT DEATHS

W. ALBERT MANDA, of Orange, New Jersey, a well-known horticulturist, died on March 15, at the age of seventy years.

GILBERT CHARLES BOURNE, emeritus professor of zoology and comparative anatomy at the University of Oxford, died on March 9, at the age of seventy-one years.

DR. ROBERT INNES, formerly astronomer for the Union of South Africa, died suddenly on March 14, at the age of seventy-one years.

WILLIAM CAWTHORNE UNWIN, the British engineer, died on March 17, at the age of ninety-four years.

Nature records the deaths of Dr. C. A. Barber, lately lecturer in tropical agriculture at the University of Cambridge, aged seventy-two years; of Sir Benjamin Gott, chairman of the Commission on Educational and Cultural Films, and formerly head master of the Cheltenham School of Science, aged sixty-seven years, and of Mr. J. J. F.-X. King, the Scottish entomologist, aged seventy-seven years. Mr. King had presented his main collection of British insects to the University of Glasgow. The university is now to receive under his will the portrait of Mr. King painted by Forrester Wilson and the remainder of his collections, together with his library of books on natural history.

SCIENTIFIC EVENTS

REPORT OF THE COUNCIL FOR CHEMISTRY

IN its report for 1932, according to a summary given in *Nature,* the Federal Council for Chemistry refers with regret to the necessary postponement of the ninth International Congress of Pure and Applied Chemistry and the eleventh conference of the International Union of Chemistry, which were to have been held in Madrid in 1932. The next meeting of the union will take place in the spring of 1934 in Madrid,