help to impart to it. Nor is this enterprise one which should influence Southern California alone, for since men of affairs come to this region as to scarcely any other region in the United States, no section is more favored than is this one in its opportunity of contributing its own good things to the progress of the country as a whole.

Finally, I wish to accept this gift in the name of all those who believe, as I do and as the trustees of this institution have from the start believed, that science in itself is not the most important thing in this world, but that the salvation of the world is to be found in the cultivation of science together with the cultivation of a belief in the reality of moral and spiritual values. Science alone may destroy this world instead of saving it, but the trustees of this institution have from the start differentiated it from most technical schools in the altogether exceptional emphasis which has been laid in its curriculum upon cultural and spiritual development. One expression of this ideal is seen in the atmosphere which has been thrown about the campus by the architectural beauty of the buildings which are already found here, a beauty which the architect, Mr. Goodhue, has known how to put in exceptional degree both into the exterior and the interior of the Norman Bridge Laboratory. I accept your magnificent gift, Dr. Bridge, in the hope and the belief that it will be an important factor in the creation at the California Institute of Technology, not only of men with the highest technical skill, but of men of the finest character and of the broadest citizenship.

R. A. MILLIKAN

A JOINT INVESTIGATION OF THE CONSTITUTION OF MATTER AND THE NATURE OF RADIATION

THE establishment of the Norman Bridge Laboratory of Physics, if my estimate is correct, is an event of no small significance in the progress of science. Dr. Millikan has explained its bearing on scientific and technical education, and pointed out that research, as conducted in the Bridge Laboratory and the Gates Chemical Laboratory, accompanied by the best instruction in physics, chemistry, and mathematics, must provide the firmest of foundations for the entire superstructure of the California Institute of Technology. It remains for me to speak of a joint investigation of the constitution of matter and the nature of radiation which the organization of the Bridge and Gates Laboratories has rendered possible.

Matter occurs in nature under the widest variety of composition and form. The physicist, who approaches this complex problem by the simplest and most direct route, deals chiefly with the chemical elements, and evolves powerful methods of research which enable him to penetrate to the core of the atom, to visualize the electrons swinging in their orbits, and to remove them one by one for detailed study. The chemist, concerned primarily with the union of atoms into molecules, and the combination of molecules of one or more elements, necessarily attacks matter of greater complexity, extending all the way from the single atom of hydrogen to compounds containing hundreds of linked atoms of many kinds. The astrophysicist, permitted by his powerful telescopes to penetrate to the depths of the universe, observes matter in the state of luminous gaseous elements, associated in the cooler stars with certain chemical compounds. The cosmic crucibles in this vast laboratory of nature exhibit conditions of temperature and pressure often transcending those attainable on earth, and thus present for observation experiments on an immense scale, the interpretation of which has already added much to our knowledge of physics and chemistry. A general study of the constitution of matter should therefore approach the problem simultaneously along the converging lines of physics, chemistry, and astrophysics.

The progress of research, particularly during the last quarter century, has brought us to the present critical juncture, when the possibilities of such a joint investigation are especially favorable. In each of the branches of science involved the methods and instruments of research have advanced to a high degree of per-

[1] Address at the dedication of the Norman Bridge Laboratory.

fection. Discovery has followed discovery, now in one subject, now in another, each throwing new and increasing illumination into the other fields. The application of the spectroscope to astronomy, affording the means of determining the chemical composition, distances, motions, temperatures, pressures, densities, and masses of the stars, has led to many advances of fundamental importance. The rise of physical chemistry, which revealed the role played by electrically charged particles in solutions and established for chemistry a rational underlying theory, opened another new world of thought. The extraordinary discoveries and developments in physics, particularly in the fields of radioactivity, the electrical nature of matter, X-rays and radiation, have brought to light wholly unexpected relationships between the elements which are of the greatest significance, both from the purely scientific and the practical point of view.

We now know that there are just 92 elements in nature, the heaviest of which are spontaneously breaking up into lighter ones. The basic element hydrogen exists throughout the universe, accompanied by other elements in varying proportions and states. A few stable elements can be broken up by artificial means in the laboratory, but no method of combining their constituents has yet been found. In the stars, however, there is strong reason to believe that the heavier elements are actually being built up from lighter ones, under conditions involving phenomena of radiation and absorption of energy as yet unknown on the earth. We should therefore not be limited to any single line of procedure, but should organize our attack in such a way that physics, chemistry, and astrophysics may all play adequate parts.

In the development in Pasadena of a single center for this purpose, the equipment needed for physics is now supplied by the establishment of the Norman Bridge Laboratory, with its powerful instruments and adjuncts, including a high tension laboratory, containing a million volt transformer, provided by the Southern California Edison Company. The Gates Laboratory, with many added facilities, will meet the necessary requirements for chemistry. The Mount Wilson Observatory, with its telescopes on Mount Wilson and its laboratories and instrument shops in Pasadena, provides for astrophysics. Thus the material means are not lacking, while the excellent atmospheric conditions, available sites for physical experiments ranging from sea-level to easily accessible mountain stations up to 12,000 feet, a neighboring Army Balloon School for free air experiments, and ample sources of hydroelectric power meet the needs of the widest research activities.

Most fundamental of all, however, is the research staff, and we are fortunate indeed in the recent accession of Dr. Millikan and Dr. Epstein, and in the privilege of having Professor Lorentz with us during the present winter. Mathematical physics must play a prominent part in our joint efforts, and the cooperation of the leading authorities in this field is essential. The combined corps of investigators of the Institute laboratories and of the Observatory, powerfully supplemented by our eminent Research Associates, is now well qualified to open an effective campaign. Indeed, if time permitted, I could show you how it has already begun.

A detailed report on the proposed joint investigation was presented by the California Institute to the Carnegie Corporation of New York in September. This was referred to President Merriam and the Executive Committee of the Carnegie Institution of Washington, who cordially endorsed the project and agreed to administer any funds for its support that might be granted by the Corporation. At its meeting on November 17 the Carnegie Corporation appropriated thirty thousand dollars per year for five years to the Carnegie Institution of Washington, to be accepted and administered by the Institution for the support of fundamental researches in physics and chemistry to be conducted at the California Institute of Technology. Dr. Millikan and Dr. Noyes have been appointed Research Associates of the Carnegie Institution, and the appropriation will be expended under their direction. Supplementing, as it does so generously, the research funds of the California Institute, this appropriation

provides the added means required for the joint investigation in conjunction with the Mount Wilson Observatory, a department of the Carnegie Institution of Washington.

It is hardly necessary to say that this liberal action is most heartily appreciated by the Trustees of the California Institute, who are thus encouraged to continue and to extend their policy of developing fundamental research in science and engineering.

GEORGE E. HALE

RESEARCH IN THE NORMAN BRIDGE LABORATORY

IT is a great honor to me to have been requested to address you on this memorable occasion and I have many good reasons for being interested in to-day's proceedings. In the first place, I have been so kindly and warmly welcomed by the scientific men of the institute that I feel almost as if I belonged to them and as if I also were going to have a share in the facilities for scientific research that have now been put at their disposal.

In the second place, I have for a long time admired Professor Millikan's important work, and I have now some idea of his great energy and activity, wondering how he can do all he does. I therefore heartily rejoice at this splendid opportunity being offered him to work on his favorite subject. He is going to have a laboratory that is worthy of him as was his wish, with Professor Noyes and his chemists and with the Mount Wilson Observatory close at hand.

But apart from these personal feelings the great development that has been inaugurated here to-day has my warmest sympathy. This would have been the case even if I never had come to this country. I am happy to say so. Indeed, even when separated by oceans, physicists form a kind of fraternity spread all over the world. It is true that the ties that unite them have not at all times been equally strong and that they have to a certain extent been severed in the disastrous period through which the world has passed. But, though we recognize that this could hardly be otherwise, we sincerely hope that in the end the feeling of good comradeship, such as is natural among men who have before them a great and important common task, will again prevail. It can not be too much emphasized that the understanding of Nature's secrets, that the use of knowledge of forces of greater urgency, and that much remains to be done, will join all workers. Certainly each individual worker will do his best to follow his own inclinations and to act according to his special abilities, and it is highly desirable that the research work of each nation bear the mark of its mentality and national aptitudes but by mutual aid and cooperation, one stimulating the other, all can be blended in one great effort.

I am deeply convinced that it must be so and therefore I feel that Dr. Norman Bridge, who is so generously promoting scientific research in this country, deserves the warm thanks, not only of Americans, but of scientific men.

And now when he takes off his evening dress, and has returned to his every-day life, Professor Millikan will set to work in his laboratory. You know what he can do, what marvels he can achieve with a single oil drop, determining, more certainly that ever was done, the electric charge and the manner and the number of the smallest particles of which matter consists. This afternoon we heard from him how he has been able to extend his investigations to ultraviolet invisible rays of the very smallest wave lengths. He is planning to send up high in the atmosphere instruments which, when safely returned to the earth, will tell about radiations which exist at great altitudes and of which he wants to trace the origin, either of the earth or the heavens. And when the high tension laboratory is ready, he and his fellow workers will bombard matter with electrons moving with a velocity comparable with that of light and they will try to knock to pieces the atoms of our elements and to see what becomes of them.

In all this they will work with Professor Noyes of the Gates Chemical Laboratory and with the astronomers of Mount Wilson. If some effect can not be found on the earth they will look for it in the sun and if there is some new and not wholly understood phenomenon in solar physics, it will be reproduced and in-