THIS PAGE LEFT BLANK INTENTIONALLY

room for possible misunderstandings and legal difficulties, which would be averted by a little foresight and promptness of action.

(Signed,) WOLCOTT GIBBS, FRANCIS A. WALKER, J. RAYNER EDMANDS, } *Committee.*

Professor Henry P. Bowditch called the attention of the Academy to the necessity of better library accommodations; and, on his motion, it was

Voted, That a committee be appointed to consider this subject.

The chair appointed the following committee: —

Messrs. Henry P. Bowditch, Josiah P. Cooke, and Henry P. Kidder.

The following gentlemen were elected members of the Academy: —

Oliver Clinton Wendell, of Cambridge, to be a Resident Fellow in Class I., Section 2.

Joseph Thatcher Clarke, of Boston, to be a Resident Fellow in Class III., Section 2.

The following papers were presented: —

"Additional Observations confirmatory of the Relation: Imperial yard + 3.37027 inches = Metre des Archives." By William A. Rogers.

"A Possible Explanation of the Discordant Values of the Equinox determined by Pond between 1820 and 1833." By William A. Rogers.

"Observations on Variable Stars by Sir William Herschel." By Edward C. Pickering. (By title.)

Seven hundred and sixty-ninth Meeting.

February 14, 1884. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a letter from the University of Edinburgh, inviting the Academy to send a delegate to its Tercentenary Celebration during Easter week.

The selection of a representative was left to the officers of the Academy.

The death of Arnold Guyot, of Princeton, N. J., Associate Fellow, was announced.

The special business assigned for this meeting was the presentation of the Rumford medals, which had been awarded at the annual meeting, in accordance with the recommendation of the Rumford Committee.

The President made the following address in presenting the medals to Professor Rowland: —

The medals awarded to Professor Rowland have been struck at the Philadelphia Mint, and appropriately engraved under the direction of the Rumford Committee. Their delivery to the recipient has been postponed for several meetings, under the hope and expectation that Professor Rowland would find it convenient to be present, and receive the medals in person. His attendance with us now is warmly welcomed, and adds greatly to the interest of the occasion. I ask your kind attention to a brief statement of so much of the scientific work of Professor Rowland as justifies the award of the Rumford premium, and of the relation in which these researches stand to the present condition and needs of physical science.

Astronomy, at least that part of it which relates to celestial mechanics, has presented for many generations unchallenged claims to a precision not attainable in any other science. The comparative simplicity of its problems, involving only the familiar and measurable units of mass, space, and time, has enabled it to attain and to hold this distinguished position, in spite of the fact that all the senses except vision are excluded from its study. If it has received any assistance from the experimental laws of mechanics, much more have these laws been illuminated by the motion of the planets, where friction and other resistances do not interfere.

After Grove, in 1842–43, had published his lectures on the correlation of the various physical forces; after Mayer, Helmholtz, and others had published their conclusions (the deductions partly of theory and partly of experiment) that these different forces were mutually convertible; and after the view first seized in prophetic vision by Bacon, Locke, and Winthrop was experimentally established by Rumford, Davy, Joule, and numerous coadjutors, and with ever-increasing clearness, that the assumed caloric was imaginary, and that heat was only one kind of motion in ordinary matter, —

then it was possible to introduce unity, harmony, and precision into all the physical sciences by making the familiar units of measurement universal. As other forms of energy (mechanical, electrical, magnetic, chemical, capillary, radiant, and gravitation) can be converted, directly or indirectly, into heat-energy, heat has become a universal standard of energy, current everywhere in science, and redeemable. Hence it has become of prime importance to determine the mechanical equivalent of heat, — the amount of heat, for example, which corresponds in energy to a given mass falling through a given height in a given latitude. In this way heat and all its dependencies will be measured by the units of ordinary work. For more than forty years, physicists in different countries, and by various methods, led by Joule, have been engrossed with this measurement, reaching results which have slowly but happily converged towards a common agreement.

Professor Rowland, after an historical and critical review of the methods and results of older cultivators in this rich field, has turned up the soil anew, deepening the furrows.

The fruits of his long and patient labor were made known to the Academy in 1879, in Volume XV. of the Proceedings. New apparatus was devised; the comparative merits of mercurial and air thermometers were discussed; and the various constants of science which enter into the case were re-examined. The research is a model of ingenious and conscientious experimentation, and was not published until it had received from its author the same severe criticism which he had applied to the work of others. That his final conclusion harmonizes so well with the best of Joule's, increases our confidence in both. A larger discrepancy might have given a greater show of originality; but science would have paid for the novelty by a loss of security, and another revision of the whole subject would have been entailed upon it.

When Newton announced his dynamical theory of the solar system, as simple as it was comprehensive, it made slow headway against the fanciful hypothesis of Descartes, which was intrenched in all the universities of Europe. And yet Newton's theory reposed upon a firm mathematical foundation; while that of Descartes submitted to no quantitative tests, and contradicted all the known laws of mechanics. The history of astronomy from that time almost to the present moment tells of ever new victories achieved by the combined attacks of the telescope and mathematical analysis in the province of celestial mechanics, presenting the law of gravitation as supreme dictator to planetary and sidereal systems. But these triumphs, complete in their details, and grand in their cosmical range, were limited to questions which concern the distances, motions, dimensions, and masses of the heavenly bodies. The law of gravitation can assign a value to the quantity of matter in planets and binary stars; but it asks and can answer no question in regard to the quality of this matter, only so far as a comparison of the size and mass of a body gives a measure of its density. That an instrument would be invented or developed which would complement the mechanics of the heavens by the chemistry of planets, comets, and stars, so that a physical observatory would become a necessary adjunct of the old observatory, was beyond the hope of the most sanguine astronomer, down to the moment of its actual realization.

Newton owes his singular fame, not exclusively to his discovery and expansion of the law of gravitation, but partly to his experimental researches in optics. That he did not recognize the dark lines in the solar spectrum has been explained by the statement that he was obliged to use the eye of an assistant in these experiments, on account of an injury to his own. Be this as it may, the existence of these lines was first known to Wollaston in 1802; and from that moment the spectroscope and spectrum-analysis, as we now understand them, were possibilities.

Although Fraunhofer made a careful study of these lines in 1824, and Brewster, Herschel, Talbot, Draper, and many others, pursued the inquiry by way of experiment and explanation, and stood upon the threshold of a great discovery, the spectroscope and spectrum-analysis, as practical realities, date from the investigations of Kirchhoff and Bunsen, in 1862. Not only does the spectroscope carry chemistry into regions tenanted only by planets, comets, stars, and nebulæ, and reveal motions in the direction of the line of vision otherwise hopelessly beyond recognition, but it competes with the ordinary chemical analysis of bodies which can be handled, and has detected new substances which had escaped the vigilance of the chemist. Some of these results can be realized with simple instruments: others require a compound spectroscope consisting of a battery of prisms. It was a great step in the way of simplicity and ease of manipulation, when the diffraction-spectrum, produced by fine lines ruled upon glass or metal, was substituted for the spectrum produced by the combined refractions of many prisms. And here we touch upon the researches of Professor Rowland in light, which enhance his claim to the Rumford premium.

Professor Rowland's improvements in the diffraction-spectrum are manifold. 1. He has substituted for the flat plate on which the grating was formerly ruled a spherical or cylindrical surface. 2. He has ruled these lines to such a degree of fineness that 5,000, or 42,000, or even 160,000, have covered only one inch. 3. This exquisite work was executed by a machine of his own invention, and produced spectra free from the so-called ghosts which result from periodical inequalities in the ruling. 4. By making the curvature of the ruled plate discharge the office of a lens, he has avoided absorption at the violet end of the spectrum. 5. By his simple mechanical arrangements, different parts of the spectrum can be photographed with a great economy of time, and with such excellence of definition that old lines are subdivided, and new ones spring into visibility. 6. The spectrum obtained is the normal spectrum. In the words of a competent authority on the subject, "the gratings of Mr. Rowland make a new departure in spectrum-analysis." 7. Finally, his mathematical exposition of the theory of gratings has explained observed anomalies, indicated the conditions of success, and prophesied the limits at which future improvements in spectrum-analysis must stop.

Professor Rowland, it is now my duty, and certainly it is a most agreeable one, to present to you, in the name of the Academy, the gold and silver medals which constitute the Rumford premium. Count Rumford, in conveying this trust to the Academy through President John Adams, expressed a preference for such discoveries as should, in the opinion of the Academy, tend most to promote the good of mankind. The practical applications of science are numerous and valuable, and are sure of popular recognition and reward; but they often come from the most unexpected quarters. No one can predict what wonderful points of contact may be suddenly revealed between a purely theoretical investigation and the practical utilities of life. Meanwhile, a deeper insight into the laws of the material universe, extorted from a reluctant Nature only after long and patient labor and thought, and many disappointments, becomes a permanent possession for mankind; and, as long as man does not live by bread alone, it is for him a perennial blessing. The Academy, in awarding the Rumford premium to you, has indicated the kind of scientific work which, in its opinion, tends most to promote the *highest* good of mankind.

I ask you to accept, with these medals, my warm congratulations, and the cordial good wishes of all the members of the Academy here assembled to administer Count Rumford's trust.

On receiving the medals, Professor Rowland spoke as follows: —

Mr. President, and Gentlemen of the Academy: —

I thank you for the honor you have conferred upon me, which I can but regard as the greatest honor of my life. In receiving these medals, I am pleased to think that they have been conferred upon work which is not the result of a happy accident, but of long and persistent endeavor.

There are some investigators whose disposition permits them to follow their aim, inspired by the mere love of the labor and the work. There are others to whom the sunshine of appreciation is necessary. To either class, appreciation, when it comes, is always acceptable; and I assure you that the judgment set upon my investigations by this Academy is highly valued by me.

It has been intimated that a short account of my work would be of interest to the members of the Academy. My attention was first called to the construction of dividing-engines by an inspection of a dividing-engine constructed by Professor W. A. Rogers, at Waltham, in this State. On returning to Baltimore, I devoted much time to the general problem of such machines; and, through the liberality of the trustees of the Johns Hopkins University, I was enabled to construct an engine. In about a year this engine was finished. It worked perfectly the moment it was put together, and it has not been touched since. In order to rule diffraction-gratings, I reflected that it was necessary that the screw should be perfect, and that the rests for the plate which receives the ruling should also be as perfectly adjusted as is necessary in optical experiments.

The process of making the screw consisted in grinding it in a long nut in which it was constantly reversed. When this screw was finished, there was not an error of half a wave-length, although the screw was nine inches long.

When the dividing-engine was completed, my mind was occupied with the problem of the best form of surface to receive the ruling. I speedily discovered, that, by ruling the lines on a concave mirror of long focus, I could dispense with a collimator and with the ordinary arrangement of lenses. I now rule gratings six inches long, with various numbers of lines to the inch. I find that there is no especial advantage in having more than fourteen thousand to the inch, with the ordinary conditions of ruling. Having made the concave grating, I invented a simple arrangement for mounting it, so that a photographic

camera should move along the arc of a circle at one end of a diameter, upon the other end of which the grating was placed, and always remain in focus. With this apparatus, one can do in an hour what formerly took days. Moreover, the spectra obtained are always normal spectra, and every inch on a photograph represents a certain number of wave-lengths.

After finishing my apparatus, I found it necessary to study photography; and I therefore devoted much time to this subject, and made a special study of all known emulsions. I discovered that an emulsion containing eocene enabled me to photograph from the violet down to the D line; and other emulsions were used for the red rays. I have also been engaged in enlarging my negatives, and in printing from these negatives. On these enlarged photographs, lines are doubled which have always been supposed to be single. The E line is easily doubled. My map of wave-lengths is based upon Professor Charles S. Peirce's measurements of the wave-length of a line in the green portion of the spectrum.

The following paper was presented by title: —

"Deducing from one Epoch to another Stars very near the Pole." By William A. Rogers.

Seven hundred and seventieth Meeting.

March 12, 1884. — Stated Meeting.

The President in the chair.

The President announced the death of Johann F. J. Schmidt, of Athens, Foreign Honorary Member; and of George Engelmann, of St. Louis, Associate Fellow.

The Corresponding Secretary read an invitation from the Royal Society of Canada to attend its third annual meeting, at Ottawa.

Professor Pickering spoke of the importance of a representation before the legislature in regard to a new topographical map of the State. The chair appointed the following committee to consider this subject: —

Messrs. Edward C. Pickering, Asa Gray, and Samuel H. Scudder.