electrical decompositions and of thermo-chemical data, or from even millions of the customary static chemical equations, would be like hoping to learn the nature of gravitation by laboriously weighing every moving object on the earth's surface, and recording the foot-pounds of energy given out when it fell. The simplest quantitative measure of gravity is, as every one knows, to determine it as the acceleration of a velocity: when we know the value of g, we are forever relieved, in the problem of falling bodies, from the necessity of weighing heterogeneous objects at the earth's surface, for they will all experience the same acceleration. May there not be something like this grand simplification to be discovered for chemical changes also?

The study of the speed of reaction has but just begun. It is a line of work surrounded with unusual difficulties, but it contains a rich store of promise. All other means for measuring the energies of chemism seem to have been tried except this: is it not, therefore, an encouraging fact, that to the chemists of the nineteenth century is left for exploration the great fruitful field of the true dynamics of the atom, the discovery of a time rate for the attractions due to affinity?

THE MISSION OF SCIENCE.[1]

AFTER thanking the section for the honor conferred upon him by electing him their chairman, and referring to the success of the meeting of the British association at Montreal, Professor Thurston announced as the subject of his address, 'The mission of science.' He spoke of his address, as vice-president at St. Louis in 1878, on the philosophic method of the advancement of science, in which he had called attention to the need of specialists, amply supplied with the proper means, to do the work of observing, collecting, and co-ordinating the results of observation. As an all-important factor in this the modern system of scientific investigation, he had spoken of the men who have given, and who are still generously and liberally giving, material assistance by their splendid contributions to the scientific departments of our colleges and of our technical schools.

It may well be asked, What is the use, and what is the object, of systematically gathering knowledge, and of constructing a great, an elaborate system, having the promotion of science as its sole end and aim? What is THE MISSION OF SCIENCE? The great fact that material prosperity is the fruit of science, and that other great truth, that, as mankind is given opportunity for meditation and for culture, the higher attributes of human character are given development, are the best indications of the nature of the real mission of science, and of the correctness of the conclusion that the use and the aim of scientific inquiry are to be sought in the region beyond and above the material world to which those studies are confined.

It being granted that the mission of science is the amelioration of man's condition, it becomes of importance to consider the way in which our knowledge is increased. While the scientific method of advancement of science is evidently that which will yield the greatest returns, it is not the fact that we are indebted to such philosophic methods for the production of the modern sciences. The inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of.

But all this is of the past. Science has attained a development, a stature, and a power, that give her the ability to assume her place in the great scheme of civilization. Hereafter she will direct and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end, — methods now daily practised by the engineer in designing his machinery.

It is only in modern times, and since the old spirit of contempt for art, and of reverence for the non-utilitarian element in science, has become nearly extinguished, and since our systems of education have begun to include the study of physical science, that we have had what is properly called a division of 'applied science.' In the days of classical learning, science was only valued as it developed a system of purely intellectual gymnastics. Archimedes was the most perfect prototype, in those days, of the modern physicist and mechanician, of the scientific man and engineer; yet he, and all his contemporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid, or the composition of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever which might 'move the world.' His enumeration of the sands of the seashore was looked upon as a nobler accomplishment than the invention of the catapult, or of the pump, which, twenty-one centuries after his death, still bears his name.

No system of applied science could exist among people who had no conception of the true mission of science; and it was not until many centuries had passed, that mankind reached such a position, in their slow progress toward a real civilization, that it became possible to effect that union of science and the arts which is the distinguishing characteristic of the age in which we live.

In illustration of the gradual evolution and growth of correct theory, and of this slow development of rational views, of the methods of scientific deduction, and of the invariably tardy progress from a beginning distinguished by defective knowledge and inaccurate logic, in the presence of what are later seen to be

[1] Abstract of an address to the section of mechanical science of the American association for the advancement of science at Philadelphia, Sept. 4, by Prof. R. H. THURSTON of Stevens institute, Hoboken, N.J., vice-president of the section.

plainly visible facts, and of what ultimately seem obvious principles, observe the rise and progress of our hardly yet completed theory of that greatest of human inventions, the steam-engine.

Studying the history of the development of this theory, it cannot fail to become strikingly evident that, throughout, experimental knowledge and practical construction have been constantly in advance of the theory; and that the science of the conversion of heat-energy into mechanical power has, in all stages of this progress, come in simply to confirm general conclusions, previously reached by deduction from experience and observation, to give the reasons for well-ascertained facts and phenomena, and often — not always promptly or exactly — to define the line of improvement, and the limitations of such advance.

The theory itself began by the correlation of the facts determined by the experiments of Rumford and Davy at the beginning of the century, those announced by Joule and Thomson many years later, and the laws developed by Clausius, Rankine, and Thomson, at the middle of the century. But Watt had discovered, a hundred years ago, the facts which have since been found to set limits to the efficiency of the engine. Smeaton, in many respects the greatest mechanical engineer of his time, made practically useful application of the knowledge so acquired, and endeavored to secure immunity from these wastes by thoroughly philosophical methods. Clarke, a generation ago, showed how the losses first detected by Watt set a definite limit, under the conditions of familiar practice, to the gain to be secured by the expansion of steam; and Cotterill, within a few years, has shown, by beautiful methods of treatment, their magnitude, and how these wastes take place. Hirn and Leloutre, in France, have similarly thrown light upon the phenomena of 'cylinder condensation,' and De Freminville has suggested the method of remedy. Yet it is only now that we are beginning to see that the philosophy of heat-engines is not simply a thermodynamic theory, and that it involves problems in physics, and a study of the methods of conduction and transfer of heat, without doing work from point to point in the engine. We are only now learning how to apply the knowledge gained by Isherwood twenty years ago, and by Hirn and by Clarke still earlier, in solving the problem of maximum efficiency of the steam-engine. We have only now discovered that the 'curve of efficiency,' as Prof. Thurston has called it, is not the curve of mean pressure for 'adiabatic' expansion, as Rankine called it; for 'isentropic' expansion, as Clausius would call it; but that it is a curve of very different form and location, and that it is variable with every physical condition affecting the working of the expanding fluid in the engine. We have only now learned that every heat-engine has a certain 'ratio of expansion for maximum efficiency,' which marks the limit to gain in economy by expansion; which limit is fixed for each engine by the nature of the expansion, and the method and extent of wastes of heat. All the facts of this case were apparently as obvious, as easily detected and weighed in their influence upon the theory of heat-engines, years ago as to-day. Even the latest phase of the current discussion of efficiencies of heat-engines, that relating to their commercial efficiency, would seem to have been as ready for development a generation ago, when first noted by Rankine, as to-day; yet what is now known as a simple and easily formulated theory has been several decades in growing into shape, notwithstanding that all the needed facts were known, or readily determinable, at the very beginning of the period marked by its evolution. It is only within a year or two that it has become possible to say that the theory of the steam-engine, as a case in applied mechanics, has become so complete that the engineer can safely rest upon it in the preparation of his designs, and in his calculations of power, economy, and commercial efficiency.

Professor Thurston then referred to the knowledge now being collected as to the strength, elasticity, and enduring capacity of the materials used in construction. But the slow progress of scientific development in matters relating to common practice in the useful arts is hardly less remarkable than the difficulty with which scientific principles, even when well established and well known among scientific and educated men, sink down into the minds of the masses. Perhaps no principle in the whole range of physical science is better established and more generally recognized than that which asserts the maximum efficiency of fluid in heat-engines to be a function simply of the temperatures of reception and rejection of heat, and to be absolutely independent of the nature of the working-fluid.

This was shown by Carnot sixty years ago, and has been considered one of the fundamental principles of thermo-dynamics from that time to this. Nevertheless, so rarely is it comprehended by mechanics, and so difficult is it for the average mind to accept this truth, that the most magnificent fallacies of the time are based upon assumptions in direct contradiction of it. The various new 'motors' recently brought before the public with the claim of more than possible perfection have taken hundreds of thousands of dollars, within the past two or three years, from the pockets of credulous and greedy victims. It is not sufficient to declare the principle: the comparison of steam with ether, and of air or gas with carbon-disulphide or chloroform, must be made directly, and the results presented in exact figures, before the unfortunate investor, whose rapaciousness is too often such as to cause him to give ear to the swindler rather than to the well-informed and disinterested professional to whom he would ordinarily at once go for advice, can be induced to withdraw from the dangerous but seductive scheme. It is true that the principle does not as exactly apply to a comparison of efficiencies of machine, and that the vender of new motors usually seizes upon this point as his vantage-ground; but a careful comparison of the several fluids, both as to efficiency of fluid and efficiency of machine, throughout the whole range of temperatures and pressures found practicable in application, such as has recently been made under Prof. Thurston's direction, shows that the final deduction is substantially the same for all the usually attainable conditions of practice, and further, that, of all the available fluids, steam is fortunately the best.

That the results of scientific investigation may be the more readily appreciated, it is necessary that the study of physical science should be more thorough in our schools. The stereotyped argument for the retention of the old system of education to the exclusion of the new, was, and is to-day, the assertion that the old system strengthened the intellect and broadened the views of the student, while the new subjects are *merely useful;* but the wisdom and the expediency of a modification of old ways, in this respect, is now rapidly becoming acknowledged, and the new education may be considered as fairly and safely introduced. Science will never, we may be sure, displace entirely the older departments of education; but science will henceforth take a place beside them as no less valuable for mental discipline.

With science recognized as a respectable companion of the dead languages, we shall have better trained students, — students who will be better able to lead in the industries, and so aid material prosperity. As it is the duty of government to so regulate affairs that each man may have the power of improving his condition to the utmost, so will it be the duty of science to point out to government how it may direct its regulations to the greatest advantage of the individual. Men of science, each in his own department, are the natural advisers of the legislator. Citizens and legislators are both entitled to claim this aid from those who have made the sciences of the several arts their special study, and from those who have devoted their lives to the study of the sciences of government, of social economy, and of ethics.

Of all the many fields in which the men of science of our day are working, that which most nearly concerns us, and that which is of most essential importance to the people of our time, is that department of applied science which is most closely related to the industries of the world, — mechanics. The development of new industries becomes as much a part of the work of science in the future as is the improvement of those now existing. The new industries must evidently be mainly skilled industries, and must afford employment to the more intelligent and more finely endowed of those to whom our modern systems of education are offering their best gifts. The enormous advancement of the intellectual side of life must inevitably, it would seem, result in the production of a race of men peculiarly adapted to such environment as science is rapidly producing. Thus accomplishing, under the guidance of science, such tasks as lie before him to accomplish, the 'coming man,' with his greater frontal development, his increased mental and nerve power, his growing endurance and probably lengthening life, will be the greatest of the products of this scientific development, and the noblest of all these wonderful works.

THE CRYSTALLINE ROCKS OF THE NORTH-WEST.[1]

UNTIL very recently, it has been the practice of geologists, almost without exception, to refer every crystalline rock in the north-west either to the Huronian or to the Laurentian. But when, on more careful examination, it is found that this nomenclature is imperfect, we are thrown into much difficulty and doubt. In order that some of the difficulties of the situation may be made clear, Professor Winchell proposed to review concisely the broad stratigraphic distinctions of the crystalline rocks that have lately been studied in Michigan, Wisconsin, and Minnesota.

Omitting the igneous rocks, which in the form of dikes cut through the shales and sandstones of the cupriferous formation, and are interbedded with them in the form of overflows, we may concisely arrange the crystalline rocks, disregarding minor differences and collating only the broad stratigraphic distinctions, in the following manner, in descending order: 1°. Granite and gneiss with gabbro; its thickness is unknown, but certainly reaches several hundred feet. 2°. Mica schist; maximum thickness, five thousand feet. 3°. Carbonaceous and arenaceous black slates, and black mica schists; thickness, twenty-six hundred feet. 4°. Hydro-mica and magnesian schists; maximum thickness, forty-four hundred and fifty feet. 5°. Quartzite and marble; normal thickness, from four hundred to a thousand feet. 6°. Granite and syenite with hornblendic schists; thickness unknown, but very great.

These six great groups compose, so far as can be stated now, the crystalline rocks of the north-west. Their geographic relations to the non-crystalline rocks, if not their stratigraphic, have been so well ascertained that it can be stated confidently that they are all older than the cupriferous series of Lake Superior, and hence do not consist of, nor include, metamorphosed sediments of Silurian, or any other age. The term 'Silurian' here is understood to cover nothing below the base of the Trenton.

Examining these groups more closely, we find: 1°. We have, beneath the red tilted shales and sandstones, a great granite and gabbro group. The gabbro is certainly eruptive, but the associated granite and gneiss are probably metamorphic. The gabbro does not always appear where the granite is present; but in other places these rocks are intricately mingled, although the gabbro can be considered in general as the underlying formation. 2°. Below this granite and gabbro group is a series of strata that may be designated by the general term 'mica schist group.' This division is penetrated by veins and masses of red biotite-granite, which appear to be intrusive in somewhat the same manner as the red granite in the gabbro. These granite veins penetrate only through the overlying gabbro and this underlying mica schist.

[1] Abstract of an address to the section of geology and geography of the American association for the advancement of science at Philadelphia, Sept. 4, by Prof. N. H. WINCHELL of the University of Minnesota, Minneapolis, Minn., vice-president of the section.