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TEACHING OF CHEMISTRY AND PHYSICS IN THE UNITED STATES.*

II.

In normal schools, the time which can be assigned to work in chemistry and physics is necessarily limited; it becomes then all-important that it should be of the right sort. As Professor Clarke points out, it is not the purpose of such schools to train specialists in any one department of learning, neither should they attempt to give a broad general education. The sole function of a normal school is to fit students for the profession of teaching.

The Bureau of Education has taken pains to enquire how far the scientific work in normal schools has complied with the plan which was originally formed to preserve them within their original functions.

On this point the report states that:

"An examination of the evidence presented in this report will show a great diversity among the various normal schools with respect to chemistry and physics. By far the larger number of them treat these sciences exactly as they are treated in secondary institutions and the smaller colleges; that is, they teach the elements of both subjects, partly by text books and partly by lectures; a few experiments are exhibited, and laboratory work on the part of the students is entirely ignored. In other words, the practice of these schools with reference to the sciences does not accord with the theory upon which they were originally founded."

A small number of normal schools, however,

"Adopt a more rational policy. Recognizing the fact that their students may be called upon to teach chemistry and physics, they endeavor to train them intelligently in methods of instruction."

Respecting instruction in chemistry and physics in universities, colleges and schools of science, much interesting matter is presented, giving in detail the actual work done in these branches of science at the most important institutions of this character.

The general conclusion drawn by Professor Clarke on the character of scientific instruction in universities and colleges is not favorable to such establishments. He says:

"Many high schools are actually doing more and better work with these sciences than is done in a very considerable number of colleges bearing good reputations."

The low standard of scientific work in universities and colleges is attributed by the report to persistent use "of the old-fashioned plan of a fix curriculum."

"Clearly these colleges could, if they would, build upon the work of the preparatory schools as a foundation, and, with no more cost of time, carry their pupils much further than they do now. The present subordinate position of scientific studies is undoubtedly due to the continuation in so many localities of the old-fashioned plan of a fixed curriculum. Given a college in which the latter still holds its own and in which the classics and mathematics have been for many years the dominant subjects of study, and we have an institution wherein but little time can be given to any one of the sciences. One term, from a third to half an academic year in length, is all that is usually allowed to chemistry. This is absurdly inadequate as one term in Latin or one term in mathematics, with no previous preparation, would be. By this system the sciences are not only underrated, but smattering is directly encouraged. The student trained in it can have no definite idea of scientific methods, scientific reasoning, or the scientific spirit. Even the professor in charge of the sciences may be himself a smatterer, teaching several branches without ever having received a systematic training in any one of them. Such teachers, who keep ahead of their classes by only a few lessons, are unfortunately very common, and with them the modern laboratory methods are simply impossible."

Professor Clarke may be correct in these general conclusions, but it is agreeable to refer to the many honorable exceptions, colleges where scientific instruction is offered on the most liberal and enlightened basis.

It would be difficult to take exception to the courses of study in Chemistry and Physics at Columbia College, New York City, where the collection of physical apparatus is the finest in the country, and three laboratories provided for the use of students.

The instruction in Physics and Chemistry at the school of mines of this college is thus described in the report:—

Physics.—Professor, O. N. Rood; mechanics is taught by Professor William G. Peck. The first year students, in the first term, take up the subject of heat, including the steam engine, and acoustics. In the second term they study optics, electricity and magnetism. The courses are illustrated by experiments and problems and are pre-

* Circulars of Information of the Bureau of Education No. 6. 1881.
A report on the teaching of Chemistry and Physics in the United States, by Frank Wigglesworth Clarke, S. B., Professor of Chemistry and Physics in the University of Cincinnati. Washington, 1881.

scribed for all students. To the third year class, lectures are delivered upon electro-statics, the mechanical theory of heat, mathematical optics, and the undulatory theory of light. Some of the lectures are accompanied by experimental demonstrations. This course is required of all students except those in chemistry, with whom it is optional.

Mechanics is taught in the third year to the students in mining engineering, civil engineering, and metallurgy. The mechanics of solids is studied in the first term and the mechanics of fluids in the second.

No physical laboratory work is mentioned in the handbook of information.

Chemistry.—Professor, C. F. Chandler; instructors, Elwyn Waller, Pierre De Peyster Ricketts, Alexis A. Julien, James S. C. Wells, Henry C. Bowen, Francis N, Holbrook, and Louis H. Laudy. General inorganic chemistry, stoichiometry, qualitative analysis, quantitative analysis, and blowpiping are required studies in all the courses. Assaying is taught to students in mining, metallurgy, and chemistry. In the geological and chemical courses, organic chemistry is studied. The chemical students have also a large amount of work in applied chemistry. Quantitative blowpipe analysis is an optional study in all of the courses.

In general chemistry the first year students attend three exercises a week throughout the year. This course is preliminary to practical instruction in the laboratory. The students are drilled upon the lectures, with free use of the best text books, and take notes which must be submitted to the professor. At the end of the year there is a rigid examination. The second class also attend three times a week during the year, and receive instruction in theoretical chemistry adapted to the needs of special scientific students.

For analytical chemistry there are three laboratories, one for qualitative analysis, one for quantitative analysis, and a third for assaying. Each of these is thoroughly equipped and is in the special charge of an instructor with an assistant. Every student is provided with a convenient table containing drawers and cupboards, and is supplied with a complete outfit of apparatus and reagents. The laboratories are open daily, except Saturdays, Sundays, holidays, and vacations, from 10 A. M. to 4 P. M.

During the second year, qualitative analysis is taught by lectures, blackboard exercises, and constant laboratory practice. The spectroscope is freely used. When the student shows, by written and experimental examination, that he is sufficiently familiar with qualitative work, he is allowed to enter the quantitative laboratory. In the third and fourth years, quantitative analysis is taught, the laboratory exercises being accompanied still by lectures and blackboard work. The laboratory course is graded after the usual manner, the student beginning with comparatively simple substances of known composition and passing on by degrees to the analysis of more complex bodies, such as coals, pig iron, various ores, slags, mattes, and so on. Both volumetric and gravimetric methods are employed. In the fourth year the student is admitted to the assay laboratory, where he is furnished with a suitable table and a set of assaying apparatus. Here he has access to crucible and muffle furnaces and to volumetric apparatus for the assay of alloys of gold and silver. The general principles and special methods of assaying are described in the lecture-room, and at the same time the ores of the various metals and their appropriate fluxes are exhibited and described. The student is then supplied with different ores and is required to assay each ore in duplicate under the supervision of the instructor.

Stoichiometry is taught, by lectures and blackboard exercises, as a part of the course in general chemistry, through the first and second years; and its practical applications are developed in lectures upon quantitative analysis and assaying.

In applied chemistry, the instruction extends through the third and fourth years and consists of lectures illustrated by experiments, diagrams, and specimens. The cabinet of industrial chemistry is very large and complete, containing several thousand specimens and materials and products.

It will be noticed that the course of study at this college is thorough, practical and technical, "the design being to train analysts and technologists." Professor Chandler has brought to bear in this work the full weight of his well-known administrative abilities, and the School of Mines of the City of New York may well be taken as a model for all future establishments of the same class on this continent.

A perusal of this report will make the fact evident, that in this country ample facilities exist for the most thorough instruction in both Physics and Chemistry, and the record shows that since the year 1865 the course of instruction in these departments of science has been one of continuous progress.

Of Columbia College, New York, we have spoken, but it might appear that we made an invidious selection if we did not refer to other prominent centres of physical and chemical research. Among many of such we may name the Massachusetts Institute of Technology; the Stevens Institute, Hoboken; the Universities of Pennsylvania, Virginia and Cincinnati; Yale, Harvard and the Johns Hopkins University. To-day the higher chemistry can be studied in a score of places where twenty years ago no adequate facilities were offered, and the modern physics, with its mathematical methods and its laboratories, is rapidly coming into vogue.

One other feature of the new movement remains to be mentioned, namely, the spread of scientific teaching downward into the secondary schools. These, too, are organizing laboratories, teaching young scholars to see and experiment for themselves, preparing the way for higher work, and rendering the latter more easily possible. The "summer schools" of chemistry at Harvard and elsewhere, the Woman's

Laboratory at the Massachusetts Institute of Technology, and such-like enterprises are doing much in this direction. To-day Chemistry and Physics are taught in nearly all the academies and high schools of the land; so that the larger colleges, whenever they see fit, may easily require from the candidate for admission a wider knowledge of these sciences than they themselves taught a dozen years ago. When and in what manner the present scientific movement shall culminate, no one can say; but the fact of growth is evident everywhere. This report is an attempt to catch the present aspect of affairs and fix it in a permanent record.

ON THE SOURCES OF ENERGY IN NATURE AVAILABLE TO MAN FOR THE PRODUCTION OF MECHANICAL EFFECT.*

By Sir William Thomson, F. R. S.

During the fifty years' life of the British Association, the advancement of Science for which it has lived and worked so well has not been more marked in any department than in one which belongs very decidedly to the Mathematical and Physical Section—the science of Energy. The very name energy, though first used in its present sense by Dr. Thomas Young about the beginning of this century, has only come into use practically after the doctrine which defines it had, during the first half of the British Association's life, been raised from a mere formula of mathematical dynamics to the position it now holds of a principle pervading all nature and guiding the investigator in every field of science.

A little article communicated to the Royal Society of Edinburgh a short time before the commencement of the epoch of energy under the title "On the Sources Available to Man for the Production of Mechanical Effect,"† contained the following:

"Men can obtain mechanical effect for their own purposes by working mechanically themselves, and directing other animals to work for them, or by using natural heat, the gravitation of descending solid masses, the natural motions of water and air, and the heat, or galvanic currents, or other mechanical effects produced by chemical combination, but in no other way at present known. Hence the stores from which mechanical effect may be drawn by man belong to one or other of the following classes:

"I. The food of animals.

"II. Natural heat.

"III. Solid matter found in elevated positions.

"IV. The natural motions of water and air.

"V. Natural combustibles (as wood, coal, coal-gas, oils, marsh-gas, diamond, native sulphur, native metals, metoric iron.)

"VI. Artificial combustibles (as smelted or electrically-deposited metals, hydrogen, phosphorus).

"In the present communication, known facts in natural history and physical science, with reference to the sources from which these stores have derived their mechanical energies, are adduced to establish the following general conclusions:

"1. *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.*‡ From it is derived the whole mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, galvanic engines, wind-mills, and the sails of ships.

"2. The motions of the earth, moon, and sun, and their mutual attractions, constitute an important source of available mechanical effect. From them all, but chiefly no doubt from the earth's motion of rotation, is derived the mechanical effect of water-wheels driven by the tides.

"3. The other known sources of mechanical effect available to man are either terrestrial—that is, belonging to the earth, and available without the influence of any external body—or meteoric—that is, belonging to bodies deposited on the earth from external space. The terrestrial sources, including mountain quarries and mines, the heat of hot springs, and the combustion of native sulphur, perhaps also the combustion of inorganic native combustibles, are actually used; but the mechanical effect obtained from them is very inconsiderable, compared with that which is obtained from sources belonging to the two classes mentioned above. Meteoric sources, including only the heat of newly-fallen meteoric bodies, and the combustion of meteoric iron, need not be reckoned among those available to man for practical purposes."

Thus we may summarize the natural sources of energy as Tides, Food, Fuel, Wind and Rain.

Among the practical sources of energy thus exhaustively enumerated, there is only one not derived from sun-heat—that is the tides. Consider it first. I have called it *practical*, because tide mills exist, but the places where they can work usefully are very rare, and the whole amount of work actually done by them is a drop to the ocean of work done by other motors. A tide of two meters' rise and fall, if we imagine it utilized to the utmost by means of ideal water wheels doing, with perfect economy, the whole work of filling and emptying a dock basin in infinitely short times, at the moments of high and low water, would give just one metre-ton per square metre of area. This work done four times in the twenty-four hours, amounts to 1.1620th of the work of a horse-power. Parenthetically, in explanation, I may say that the French metrical equivalent (to which in all scientific and practical measurements we are irresistibly drawn, notwithstanding a dense barrier of insular prejudice most detrimental to the islanders),—the French metrical equivalent of James Watt's "horse-power" of 550 foot-pounds per second, or 33,000 foot-pounds per minute, or nearly 2,000,000 foot-pounds per hour, is 75 metre-kilogrammes per second, or 4½ metre-tons per minute, or 270 metre-tons per hour. The French ton of 1000 kilos, used in this reckoning, is 0.984 of the British ton.

Returning to the question of utilizing tidal energy, we find a dock area of 162,000 square metres (which is little more than 400 metres square) required for 100-horse power. This, considering the vast costliness of dock construction, is obviously prohibitory of every scheme for economizing tidal energy by means of artificial dock basins, however near to the ideal perfection might be the realized tide-mill, and however convenient and non-wasteful the acumulator—whether Faure's electric accumulator, or other accumulators of energy hitherto invented, or to be invented,—which might be used to store up the energy yielded by the tide mill during its short harvests about the times of high and low water, and to give it out when wanted at other times of six hours. There may, however, be a dozen places possible in the world where it could be advantageous to build a sea-wall across the mouth of a natural basin or estuary, and to utilize the tidal energy of filling it and emptying it by means of sluices and water-wheels. But if *so* much could be done, it would in many cases take only a little more to keep the water out altogether, and make fertile land of the whole basin. Thus we are led up to the interest-

* British Association, 1881.

† Read at the Royal Society of Edinburgh on February 2, 1852. (*Proceedings* of that date.)

‡ A general conclusion equivalent to this was published by Sir John Herschel in 1833. See his "Astronomy," edit. 1849, § (399.)