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THEODORE WILLIAM RICHARDS

ON April 2, 1928, the scientific world was shocked by news of the death after a short illness of Theodore William Richards, Erving professor of chemistry in Harvard University. Until within three weeks of his death he performed his usual duties, but from that time he failed rapidly. His father, William Troost Richards, noted marine artist, as well as his mother, Anna Matlock Richards, were natives of Pennsylvania, and it was in Germantown, Pennsylvania, on January 30, 1868, immediately after the return of his parents from a European trip, that Theodore Richards, the fifth child, was born.

Childhood was passed under stimulating surroundings. His father was a very wise and far-seeing man as well as an artist; his Quaker mother an author of both prose and poetry; his three brothers and two sisters as well as he possessed a rich intellectual inheritance; artists, authors and scientists were intimate family friends at his father's Germantown and Newport homes; two years were spent in Europe, largely in England. By a wise decision on the part of his parents, Richards's early education up to the time of entering college was obtained at home from his mother. His quick intelligence was impatient of delay, and to conform to normal educational speed would unquestionably have been irksome if not disastrous. Although he was prepared to enter Haverford College at the age of thirteen and one half, because of his youth entrance to college was postponed for one year. But in the meantime he undertook the studies of the freshman year at home, still under the tutelage of his mother, and joined the sophomore class at Haverford in the fall of 1882.

Scientific interest showed itself early. As a boy he lived through two "boughten" sets of chemicals unharmed, and while still at home was taken into the chemical laboratory of the University of Pennsylvania Medical School by Dr. Marshall and given special instruction in qualitative analysis. In Haverford College, under Professor Lyman B. Hall, he laid a firm foundation for his future work in chemistry, although his interest at that time was divided between chemistry and astronomy. Possibly only the accident of defective eyesight deterred him from selecting the latter field for his life work, but it is probable that acquaintance with Professor Josiah P. Cooke, of Harvard, who was a summer neighbor at Newport, exerted a strong influence on his decision. At any rate, after graduating with high honors at Haverford in 1885, he entered Harvard College as a senior specializing in chemistry. In order to do this it was necessary for him to pass the examination in Greek for entrance to Harvard. Again, with the help of his mother, he succeeded in preparing for the examination in six weeks of study during the summer. As a senior at Harvard his time was devoted to completing under Professors Cooke, Charles L. Jackson and Henry B. Hill the fundamental preparation necessary for advanced work in chemistry. On commencement, 1886, the bachelor of arts degree was awarded with highest honors in chemistry, *summa cum laude*.

At Harvard the influence of Cooke upon Richards was immediately apparent. Cooke's interests were largely in the field nowadays labeled physical chemistry, partly by inclination, partly perhaps through association with the French physicist Regnault, under whom he had worked some years earlier as a student. One of Cooke's earliest publications concerned the numerical relations between the atomic weights of similar elements. But this investigation had made clear to Cooke the necessity for more accurate determinations of the atomic weights and he had undertaken the experimental revision of some of these constants. Under Cooke, Richards, as a graduate student at Harvard, carried through a redetermination of the relative atomic weights of hydrogen and oxygen, which holds its place to-day as one of the outstanding determinations of this important ratio. No problem of the sort could have presented more difficulties than did this one, and in this investigation appear all the qualities which later were so vital for the work which Richards was to do. An infinite capacity for taking pains, an uncompromising attitude toward the possibilities of hidden errors, a determination to be certain that no precaution had been overlooked, an extraordinary persistence in the patient repetition of exacting and laborious experiments were combined with unusual manual dexterity and ingenuity, the exercise of which must have given great satisfaction to the possessor. One can not but feel that although these qualities would unquestionably have brought success wherever they were directed, chance favored him in presenting at the outset a field in which his talents could be so profitably employed.

After receiving the doctor's degree in 1888 at the age of twenty, Richards spent the following year as the holder of a traveling fellowship in study at German universities under Jannasch, Victor Meyer, Hempel and others. His plan of devoting half of the year abroad to intensive study in one institution, followed by a half year of peripatetic study, was one which he always advocated afterward to students with a similar opportunity, as offering on the whole the greatest good for the time available.

In the fall of 1889 he returned to Harvard as assistant in quantitative analysis, never again to break his connection with the university as a teacher. Promotion to an instructorship came in 1891 and to an assistant professorship in 1894. In 1901 he received the very unusual honor, at that time, of a call to a chair in a European university. The University of Göttingen invited Richards to accept a full professorship in chemistry, with only nominal teaching duties beyond the conducting of investigation. To a man impatient to make rapid progress in research, but working with a heavy teaching load, in a laboratory far from ideal, such an opportunity was tempting in the extreme. Fortunately Harvard appreciated the value of the promising young scientist and rose to the occasion with the offer of a full professorship and an agreement of a drastic reduction in the amount of teaching and administrative duties expected. Upon the retirement of Professor Jackson in 1912, Richards was appointed to the Erving professorship, founded in 1792, the oldest endowed professorship in chemistry in Harvard University.

Immediately after his return from Europe to Harvard in 1889 Richards reentered the field of chemical investigation in which he had already made a beginning, and which was to occupy a large part of his attention during the remainder of his life. Always convinced that only through a precise knowledge of the properties of matter was progress in chemical science to be made, he was fond of making the following quotation from Plato, "If from any art you take away that which concerns weighing, measuring and arithmetic, how little is left of that art!" Furthermore, at that time the atomic weights and the Periodic Law seemed to him to offer more promise of contributing to the understanding of the laws of the universe than any other field of chemistry. In a paper printed in 1910 he says:

> But some may contend that the very exact determination of these quantities is after all an abstract and academic question, not of great practical significance. How will this remote philosophical knowledge yield any practical use? Who can tell? Faraday had no conception of the electric locomotive or the power plants of Niagara when he performed those crucial experiments with magnets and wires that laid the basis for the modern dynamo. When mankind discovers the fundamental laws underlying any set of phenomena, these phenomena come in much larger measure than before under his control and are applicable for his service. Until we understand the laws, all depends upon chance. Hence, merely from the practical point of view of the

progress of humanity, the exact understanding of the laws of nature is one of the most important of all the problems presented to man; and the unknown laws underlying the nature of the elements are obviously among the most fundamental of these laws of nature. In brief, that is the reason why more than twenty years ago the systematic study of the atomic weights was begun at Harvard University by the author.

Observations during the work upon hydrogen under Cooke led him to suspect inaccuracy in the atomic weight of copper and this subject engaged his energies both before and after his trip to Europe. The thoroughness with which this work was done was characteristic. In order to avoid the danger that a single method might be affected by some constant undetected error, not one but several methods were employed, after each method had been scrutinized with the greatest care. The copper was subjected to the most elaborate purification, and in order to make sure that copper always possesses the same atomic weight, no matter where it occurs in the earth's crust, specimens from widely different sources were examined. As a result of this work a new value for the atomic weight of copper was obtained which has shown no evidence of requiring even slight alteration up to the present. The research on copper was followed by similar investigations upon the atomic weights of other common elements, barium, strontium and zinc being those next attacked. Up to the time of his death, either with his own hands or with the aid of assistants, Richards redetermined the atomic weights of twenty-four of the eighty-four elements which have been isolated in quantity.

Greater academic responsibilities, as well as an increasing number of research students, early made it out of the question for him to carry on a large amount of experimental work with his own hands, so that in much of his later investigations the laboratory manipulation was performed by assistants. The necessity for this is obvious if it is remembered that an expert might spend all his time for a year or even several years in the determination of a single atomic weight.

In the course of this work many new analytical processes were devised and old ones perfected. New methods of purification were invented and new criteria of purity established. Especially Richards appreciated the extreme difficulty, not previously recognized, of freeing substances, otherwise pure, from the ever-present water, and devised the well-known "bottling apparatus" for enclosing and preserving the carefully dried substances in a dry atmosphere preparatory to weighing. The "nephelometer" for comparing and measuring traces of solids suspended in liquids was another product of necessity. The importance of taking into account the solubility of "insoluble" substances was pointed out and the great danger of the contamination of precipitates through inclusion and occlusion was emphasized. All these perfections of analytical methods have been of subsequent service not only in the determination of atomic weights but in analytical chemistry in general.

At the outset of Richards's career the work of the Belgian chemist Stas upon atomic weights was universally accepted as representing the nearest approach to perfection which had ever been attained. Constant study of Stas's work enabled Richards to improve upon the former's methods in many ways, without, however, at first arousing any suspicion of inaccuracy in Stas's experiments. For the most part the work of the two had not overlapped, and there had been insufficient basis for comparison. But ultimately discrepancies began to appear, and in 1904 a redetermination of the atomic weights of sodium and chlorine was completed which showed conclusively that in the case of these elements Stas's work was vitiated by appreciable errors not difficult to trace. Subsequent developments in Richards's laboratory have shown that Stas, although years ahead of his time, was in error by important amounts in nearly all his work. A new era in analytical accuracy was thus inaugurated by Richards and the students who worked under him.

Later, in 1913, when the question was raised of probable differences between the atomic weight of common lead and those of isotopes of radioactive origin, it was to Richards's laboratory that Dr. Max Lembert was sent from Karlsruhe with specimens of uranium lead in order to settle this important question. The first direct evidence of the lower atomic weight of uranium lead resulted from their investigation.

Richards is most widely known for his work on atomic weights. It was this work which brought him membership in the American Academy of Arts and Sciences at the age of twenty-three and in the National Academy of Sciences at the age of thirty-one, as well as the Nobel prize at forty-seven. From 1899 to 1902 he was a member of the International Committee on Atomic Weights and since 1919 of the International Committee on Elements and the subcommittee on atomic weights. He never lost interest in this field, and there has seldom been a time when the investigation of one or more atomic weights has not been under way in his laboratory. Furthermore, the experience in exact methods thus obtained was invaluable in the quantitative development of other fields in which he ultimately became interested.

While Richards's original contributions in fields of physical chemistry other than that of atomic weights are too numerous and varied to be described in detail here, certain phases of the work should be emphasized because they represent steps in advance as important from the standpoint of precision as his determinations of atomic weights. His first published paper was concerned with a minor problem in thermochemistry, the constant heat of precipitation of silver chloride. Later, recognizing that this portion of the field of thermodynamics was of fundamental importance, he devoted much time and energy to its practical and theoretical aspects. From a practical point of view he endeavored very successfully to increase the accuracy of thermochemical measurements. This was largely effected by means of the "adiabatic calorimeter" in which the calorimeter is surrounded with a larger vessel, the temperature of which is caused to follow closely that of the calorimeter during the experiment. This ingenious device, original with Richards, although the suggestion had been made earlier by Person, enables the troublesome corrections for loss of heat to or gain of heat from the surroundings and for lag of the thermometer to be avoided. With this apparatus he made accurate measurements of the specific heats of solids at low temperatures, the specific heats of liquids, the heats of evaporation of liquids, the heats of solution of metals in acids, the heats of combustion of organic substances and heats of neutralization.

From a theoretical point of view he early recognized the importance of alteration in the heat capacity of a system undergoing a chemical change, and several years before the publication of the third law of thermodynamics by Nernst, he pointed out the close relation between this alteration and the difference between the "total energy change" and the "free energy change" during a chemical reaction.

Richards was the first to make exact determinations of the transition temperatures of hydrated salts, and to suggest their advantages as fixed points in thermometry, since extreme alterations in the temperature of the thermometer may be avoided by their use.

In electrochemistry Richards made very detailed investigations of the copper and silver coulometers, and showed that Faraday's Law holds with great exactness both in aqueous solution and with fused salts. The study of single potential differences, especially that of iron under varying conditions, and of the electromotive forces between amalgams of different concentrations has engaged his attention at various times.

For more than twenty-five years Richards's activity was very largely concerned with the experimental and theoretical consideration of the apparent volumes and compressibilities of the chemical elements. Experimentally this involved the devising and using of new forms of apparatus for the very exact measurement of the compressibilities of the elements and their compounds, as well as the related properties, surface tension and heat of evaporation. He first developed clearly the close parallelism between atomic volume and compressibility, and the relations between compressibility and increase or decrease in volume during a chemical change on the one hand and chemical affinity and cohesion on the other, and called attention to the extreme improbability of constant atomic volume of an element in different states of chemical combination. In recent years he was engaged in the derivation of a mathematical expression for computing from the compressibilities and other data the actual internal pressures which hold matter together, and had obtained extremely interesting and striking results. The importance of the facts and generalizations in this field brought forward by Richards is beyond question, and while he had made little effort to correlate them with the most recent ideas of the constitution of matter, there seemed to be no conflict in the two points of view.

Besides the foregoing topics many problems in chemical equilibrium and in analytical chemistry are included among the subjects considered in the nearly three hundred scientific papers published during his forty years of activity as an investigator.

While it is always difficult to evaluate the ultimate importance of contemporaneous advances in any field, I believe that every one will agree that Richards's contributions to the technique of precise physicochemical investigation will always stand out prominently in the history of this period of American chemistry. In time further advances will surely come, just as Stas and Richards himself were able to make vast improvements on the existing situations. Doubtless Richards could have carried the refinement of his work to a greater extreme if the needs of the time had required it. Certainly up to the present no one else has done so.

To me one of the most striking features of his work is the uniform care with which every aspect of an investigation was considered and every contingency foreseen. It was never his way to close up the bunghole and leave the spigot open. This was due in part to never losing sight of the fact that measurements, no matter how accurate, are of no permanent value unless the materials being measured are of undoubted purity and definiteness, and the process free from defects, but in part it was undoubtedly due to an excessively cautious temperament, which probably saved him from making false steps. To one familiar with the experimental methods of his laboratory, it is interesting to see the widespread adoption of these methods by other laboratories in the fields where they are applicable.

It was Richards's belief that his career as a scientific investigator brooked no interference outside the inevitable calls of the university and his home. For this reason he never found time for the writing of books. Aside from several monographs printed by the Carnegie Institution and a collection of papers printed in Germany, his writings were confined to scientific papers, addresses and biographies. For the same reason he was always unwilling to undertake technical or consulting work. And especially during recent years he was seldom seen at scientific meetings because he found the necessary journeys and the attendant excitement too much of a drain on his store of nervous energy.

It was not only as an investigator that Richards's influence was very great. His teaching experience began while he was a graduate student, when he served as a laboratory teaching assistant. In the summer of 1890 he taught elementary chemistry in the Harvard Summer School and devised for the purpose a new inductive method of presenting the subject. This method was later adopted by Harvard University as the approved method of preparing for the entrance examination in chemistry, and exerted a profound influence on the teaching of chemistry in secondary schools, especially in New England. He taught quantitative analysis in Harvard College from 1889 to 1902. In the advanced course the lectures were largely devoted to the application of the most recent advances in physical chemistry to analytical chemistry, an unusual thing at that time. In 1895 the death of Professor Cooke left the course in physical chemistry without a permanent instructor. Richards spent the late spring and summer in Germany studying under Ostwald and Nernst, and in the following year gave for the first time the advanced course in physical chemistry with which he was associated during the remainder of his life. This course dwelt especially with the underlying causes of phenomena without involving the student hopelessly in mathematical details. Since the members of the course were largely graduate students, in order to keep in touch with the undergraduates, Richards gave the whole or a part of a course in elementary physical chemistry presented from an historical standpoint, a side of the subject which he considered of very great importance. Since he possessed to a high degree the faculty of understanding the difficulties of others and of presenting a subject in a simple and illuminating way, these courses were always especially valued by both the students and his colleagues. Fortunate as are those who have had the privilege of hearing his lectures, even more so are those who were his collaborators in research. His daily visits to the laboratories of his research students invariably brought encouragement and inspiration, either through his enthusiasm or by crucial suggestions. Satisfied with nothing but the best, he aroused the students to new levels of carefulness and thoroughness, at the same time insisting on a judicial sense of proportion as to the essential and the non-essential. What wonder therefore that not only American students came to Cambridge for his instruction, but also selected pupils from European institutions, who were sent to his laboratory for special training in exact measurements, a reversal of the old order! Of these, Gilbert N. Lewis in America and Otto Hönigschmid in Germany are best known. In 1907 he spent the second half year at the University of Berlin as exchange professor, the only instruction which he ever gave away from Cambridge.

Although theoretically exempt from administrative duties after his call to Göttingen, in time of need he did not hesitate to step into the breach as Chairman of the Divison of Chemistry from 1903 to 1911, and in this capacity served the Division with the most conscientious attention to detail and with far vision for the future.

All of Richards's early experimental work was performed under most trying conditions in an old and inadequate structure. At no time could he feel sure that noxious gases produced in some remote part of the building would not find their way into his laboratory to ruin the products of days or weeks of labor. On one occasion the ceiling of his laboratory was brought down about his ears by a miniature flood in the room overhead. At this period constant watchfulness to avoid untoward accidents of this sort was as important for his work as analytical skill. That he was able to carry on his work at all under these conditions is a splendid example of the superiority of man over circumstances. Visions of a new laboratory, with freedom from dirt and fumes as well as vibrations, were in his mind almost from the outset. At times the fulfilment of his hopes seemed so imminent that he prepared detailed plans for a research laboratory for exact work, only to be met with disappointment. It was not until 1912 that he was enabled to realize his ambitions in this direction. Largely through the generosity and interest of Dr. Morris Loeb, funds for a research laboratory of physical chemistry were secured. Richards immediately set about the perfecting of the designs of an ideal laboratory with the same care, thoroughness and imagination with which he undertook a scientific investigation. In equipment, convenience, freedom from fumes and dirt, and from rapid temperature changes the Wolcott Gibbs Memorial Laboratory has probably never been equalled.

The list of honors which he received was a most imposing one. Between 1905 and 1923 he was the recipient of honorary degrees of D.Sc. from Yale, Harvard, Cambridge (England), Oxford, Manchester and Princeton; of LL.D. from Haverford, Pittsburgh and Pennsylvania; of Ph.D. from Prague and Christiania; of Chem.D. from Clark, and even of M.D. from Berlin. The Davy Medal of the Royal Society (London) was received in 1910. On the occasion of the award to him of the Faraday Medal of the Chemical Society (London) in 1911 he delivered an address on "The Fundamental Properties of the Elements." In 1912 the award of the Gibbs Medal of the Chicago section of the American Chemical Society was the occasion of an address on "Atomic Weights." The Franklin Medal was given to him by the Franklin Institute in 1916. The second American scientist and the only American chemist to receive the Nobel Prize, that of 1914 awarded in 1915, he was deterred by war conditions from visiting Sweden at that time, and when later, in 1922, he went to Europe with the intention of delivering the Nobel address, the critical illness of his older son, who accompanied him, again interfered with his visit to Scandinavia. At this time he was given the LeBlanc and Lavoisier Medals of the French Chemical Society. In 1925 he was made an officer of the French Legion of Honor.

Besides holding membership in various American scientific societies he was a vice-president of the Eighth International Congress of Applied Chemistry in 1912, President of the American Chemical Society in 1914, of the American Association for the Advancement of Science in 1917, of the American Academy of Arts and Sciences in 1919–1921, and was to serve as the Honorary Chairman of the September, 1928, meeting of the American Chemical Society. Honorary memberships in the Royal Institution of Great Britain, the Chemists' Club of New York, the Harvey Society, the Franklin Institute, the Royal Irish Society, the Royal Society of Edinburgh, and the French Chemical Society were received in that order. He was Foreign Member of the Swedish Academy of Sciences, the Royal Italian Academy (dei Lincei), the Royal Society of London and the Danish Royal Academy, and Corresponding Member of the Prussian Academy of Sciences, the Brooklyn Institute of Arts and Sciences, the Royal Academy of Sciences of Bologna and the French Academy of Sciences. In 1908 he was appointed Lecturer in the Lowell Institute in Boston and gave a series of lectures on the "Atomic Theory." He was a member of the National Research Council from the time of its organization throughout the war, and during the war was Consulting Chemist under the War Department. Since 1902 he had been a Research Associate of the Carnegie Institution.

It is seldom that an endowed professorship is named for a person then living, but in 1925 Richards's friends were delighted by the announcement that Mr. Thomas W. Lamont, in memory of his brother, Hammond Lamont, had established at Harvard, the Theodore William Richards professorship of chemistry.

Genial and social in his inclinations and with a whimsical sense of humor, he was a welcome addition to any gathering, for his interests included practically every form of human activity, especially art and music. His artistic inheritance might well have been developed as his vocation. As a youngster he planned to follow in his father's footsteps, and always obtained enjoyment from exercising his ability to sketch and paint. One of the most interesting sights in the Gibbs Laboratory was a marine picture which was the joint production of father and son. He was particularly warm-hearted and generous towards his friends. No trouble was too great for him to take in their interests, and no pleasure greater than his at their success. To me the thirty-five years of close association with Richards as his pupil, colleague and friend will always be one of the greatest privileges of my life.

Although never an athlete in a strict sense, he was fond of various outdoor sports. He was especially interested in yachting, and for many years as a young man spent a portion of his summers on his cruising yawl. At one time he was a good tennis player, and he was one of the earlier devotees of golf in America. The latter pastime he never gave up.

In 1896 Richards was married to Miss Miriam Stuart Thayer, daughter of Professor Joseph Henry Thayer, of the Harvard Divinity School. Of their three children, Grace Thayer is the wife of Professor James B. Conant, of Harvard; William Theodore has inherited his father's scientific tastes and is Assistant Professor of chemistry at Princeton University, while Greenough Thayer is a student of architecture.

His domestic inclinations were very strong and his wife's appreciation of his work was extraordinarily sympathetic. It would be hard to decide which was the greatest, his devotion to his family, to Harvard University, or to science, but it is certain that no one could have been more forgetful of self in the interest of any of them. His creed with relation to the last one of the three has been left in his own words, and is typical of his desire to give faithful service;

"First and foremost I should emphasize the overwhelming importance of perfect sincerity and truth;

one must purge oneself of the very human tendency to look only at the favorable aspects of his work, and be ever on the lookout for self deception (which may be quite unintentional). Next, one should never be content with a conventional experimental method or scientific point of view;—one should be open-minded as to the possibility that the procedure or hypothesis may be incomplete. Each step would be questioned, and each possibility of improvement realized. And then, patience, patience! Only by unremitting, persistent labour can a lasting outcome be reached."

GREGORY P. BAXTER

"STANDARDS" AND THE TEACHING LOAD IN SCIENCES

AMONG the "standards" for our colleges and schools formulated by various standardizing and accrediting agencies is usually to be found one that sets a maximum load for teachers. The unit in which the maximum is expressed is the lecture or recitation period. No standardizing agencies attempt in their formulation of standards to differentiate among the various subjects in estimating the teaching load, but some recognize the appropriateness of such differentiation in the administration of their provisions. A number do, however, attempt in their formulated standards to evaluate laboratory work, teaching of other types or auxiliary teaching services in terms of lecture or recitation periods. The evaluation of laboratory work is of peculiar interest to the scientist. It is the purpose of this paper to call the attention of scientists and educators to the fact that the evaluation of laboratory work when embodied in formal "standards" and in practice under less specific provisions is frequently unfair to the teacher of sciences and constitutes in certain cases a serious obstacle to effective teaching.

It is, of course, recognized that many colleges and schools have their own ideals, their own standards for teaching loads, and their own practices in weighing laboratory work in comparison with other types of instruction. So long as these ideals are not lower, the teaching loads not greater and the practices not less liberal than those approved by the standardizing agencies they may be little affected by the agency standards. But many institutions depend upon these agencies to fix their ideals. Some, at least, consider the teaching load set as the maximum by the standardizing agency to be the normal load for their teachers. It is, consequently, of importance that the standards be arrived at with due regard to facts and that they be administered in the light of actual conditions.

Not long ago a man who holds a professorship in a non-science department of a college was comparing the amount of work required of a student in his own courses with that in courses given in other departments. He inquired as to the number of pages in the text used in a particular course in a science and received in reply indication of what to him, manifestly, appeared a very small number. He completed, as he thought, the demolition of his opponent's position with, "And a lot of these pages are taken up with pictures, aren't they?" It is to be feared that many persons, even in educational work, regard the pictures in our texts as so much "filling," expensive filling, necessitated by the styles set by our publishers but justifying slight attention on the part of the student. It is to be feared that many persons regard laboratory work in much the same light—as merely an expensive, fashionable adjunct to the real work of teaching, not making any great demands on teacher or pupil. Indeed, some may be found maintaining that the laboratory is the recreation ground of the teacher of science and that, far from being paid for services there, he might reasonably be required himself to pay a fee, in lieu, for instance, of dues in the country club. It is true that many scientists, by their devotion to the work in their laboratories, lend a certain apparent justification to this view, but it is fundamentally unsound.

The time and energy required by laboratory work varies with the subject, the size of the class and various other conditions, as is true of other types of instruction. In general it may be said that proper conducting of laboratory work involves, while it is in progress, an expenditure of energy on the part of the instructor at least equivalent to that of conducting a classroom recitation. There is the same necessity for quickly sensing the point of view of student after student and for taking measures for eliciting appropriate reactions. But in the typical recitation the attention of the attentive pupils is centered on a common point of discussion. In the laboratory, on the other hand, each properly attentive student is engaged on his separate study; and the instructor, as he turns from one student to another, must constantly shift his attention from one subjective situation to another, from one experiment, one sample of material, one type of difficulty, to another. Furthermore, laboratory work in schools and the great bulk of collegiate laboratory teaching is elementary in character and involves varied materials and methods, for which a maximum of promptly available information and of skill and energy in teaching is demanded. Outside of the periods of actual conduct of laboratory work, there is involved on the part of the teacher a large