NATIONAL ACADEMY OF SCIENCES

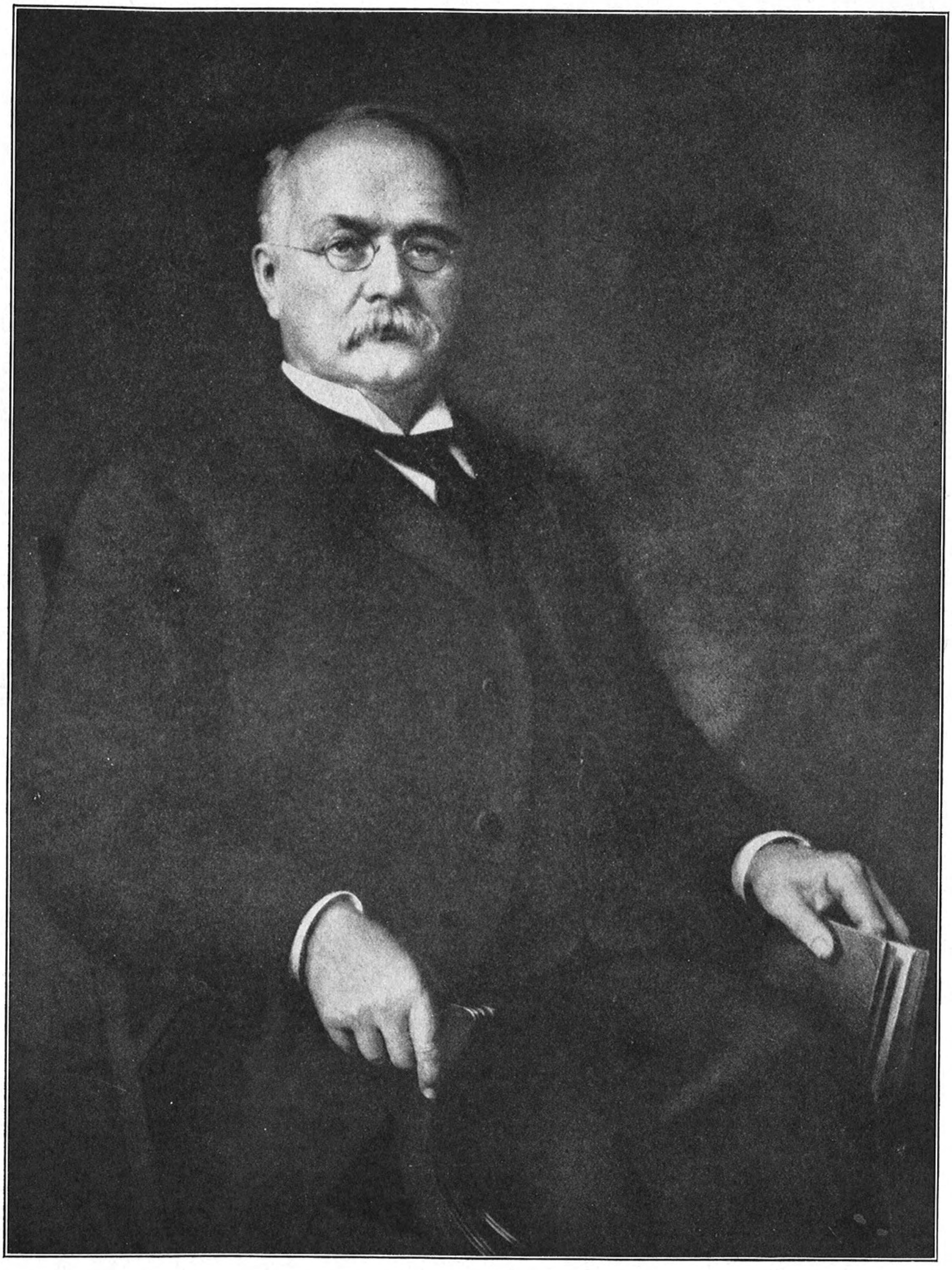
Volume XXI
ELEVENTH MEMOIR

BIOGRAPHICAL MEMOIR HARMON NORTHROP MORSE

BY

IRA REMSEN

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1923



Harmon N. Morse

HARMON NORTHROP MORSE

Compiled by Ira Remsen

Harmon Northrop Morse was born and brought up among the Green Mountains in a most picturesque region of rugged Vermont. The Lamoille River flows about his father's farm and is full of wild beauty. Ancient forests clothe the mountains, and the clearest of brooks sparkle as they rush down the hillsides.

His earliest paternal American ancestor was John Morse, who came from England in 1639 and settled at New Haven.

His father, Harmon Morse, was a believer in hard work, few holidays, and little schooling. He looked upon all forms of recreation as objectionable. The death of the boy's mother when he was too young to remember her removed a much-needed gracious and loving influence. His brother Anson and his young sister Delia were comrades and comforters in his life, which for the most part lacked the elements of love and geniality.

The courage and ambition of the boy overcame all obstacles and difficulties. His maternal grandfather left a legacy whereby each of the three children was enabled to prepare for higher education, and thus Harmon was led to Amherst College, entering in 1869.

His passion for work and his keen and investigating mental processes dated back to his boyhood days, and were a heritage from his honored forefathers.

He was born at Cambridge, Vt., October 15, 1848, and died September 8, 1920. He was married December 13, 1876, to Caroline Augusta Brooks, of Montpelier, Vt. She died in 1887. He was married again, December 24, 1890, to Elizabeth Dennis Clarke, of Portland, Me. She survives him.

Having thus in brief outline stated a few of the main facts in the life of Professor Morse, it now seems best to let some of those who knew him best tell of him and his work. Shortly after his death, the compiler of this notice was asked to prepare a sketch for Science. This was published November 26, 1920, and is here reproduced. On Sunday, April 24, 1921, a meeting in memory of Professor Morse was held at the Johns Hopkins University. President Goodnow presided at the meeting. Addresses were made by former President Remsen, for many years a colleague and friend of Professor Morse; President Woodward, of the Carnegie Institution of Washington; Prof. J. C. W. Frazer, of the Department of Chemistry; and Dr. W. H. Howell, of the School of Hygiene and Public Health. As Doctor Remsen spoke without manuscript, the brief article from Science is substituted for his address. The addresses of the others named are given in full.

I. DOCTOR REMSEN'S ARTICLE FROM SCIENCE

After a long life spent in service in Johns Hopkins University, Professor Morse died September 8, in the seventy-second year of his age. He was born October 15, 1848, at Cambridge, Vt., the son of a farmer, and died at Chebeague, Me., where he had spent his summers for many years. He was graduated from Amherst College in 1873, then went to Göttingen, and received the degree of Ph. D. from that university in 1875. The year 1875–76 was spent at Amherst as assistant in chemistry. In 1875 it was announced that the Johns Hopkins University would begin its work in 1876. Shortly after it became known that the writer of this notice was to be the professor of chemistry in the new university he received a call from Morse, who brought a letter of introduction from Emerson. This letter led me to take more than ordinary interest in the bearer. Whatever we were to do in Baltimore, it seemed clear that I should need an assistant, and I told him I would in due time arrange for his appointment. Hearing a little later of the fellowships that were to be awarded, I secured one of these for Morse, and so his connection with the Johns Hopkins University began. Before the doors were opened, however, he was designated associate, and we began our work together for better or for worse. We had no laboratory. We had less than a handful of students. What was to come of it? I need not go into the story thus suggested except to say that we were absolutely untrammeled and left to work out our own salvation. Morse and I were of one mind as to the object to be attained, and there were no discussions in regard to the methods to be adopted. They were not original, but they had never been tried in this country. There had never been an opportunity. The opportunity that many of us had hoped for, had dreamed of, was furnished by the bounty of Johns Hopkins and the wisdom of his trustees and of President Gilman.

Morse remained an associate until 1883, when he became an associate professor. In 1892 he was promoted to be professor of inorganic and analytical chemistry, and in 1908 he became director of the chemical laboratory. In 1916 he withdrew from active service and became professor emeritus.

From the beginning of our work in the new university the importance of research was emphasized. That was indeed its most characteristic feature. Morse was as anxious as any of us to take part in this work. For one reason and another it was some time before he got going. To be sure he did show his hand in some small and rather unpromising pieces of work, and I think he became discouraged, but he was faithful to his teaching. Gradually, however, his researches opened up new fields and he began their exploration. This is not the place for a full review of his contributions, and those of his last years so overshadowed all that preceded that a reference to those alone will do substantial justice to his memory.

In the early nineties he turned his attention seriously to the question of the stability of solutions of potassium permanganate, and in 1896 he published an article on "The reduction of permanganic acid by manganese superoxide," A. J. Hopkins and M. S. Walker appearing as joint authors. Pursuing this subject Morse and H. G. Byers in 1900 published an article "On the cause of the evolution of oxygen when oxidizable gases are absorbed by permanganic acid." The results were such that it became desirable to obtain an aqueous solution of pure permanganic acid. It was decided to prepare this by dissolving the heptoxide in water. In an article by Morse and J. C. Olsen that appeared in 1900 occurs the following passage:

> [We] accordingly prepared a quantity of the anhydride by mixing potassium permanganate and concentrated sulphuric acid in vessels cooled by ice and salt. We soon learned, however, that something more than a low temperature is essential to safety in handling the product; for a minute quantity of the anhydride—certainly less than half a drop—which had been separated from the sulphuric acid, exploded with great violence and with disastrous results to one of us.[1] Some idea of the force of the explosion may be gained from the fact that one of the flying fragments of glass passed entirely through a burette which was mounted in the vicinity, leaving holes over half the diameter of the burette, edges of which were entirely free from cracks. After this experience, we decided to abandon the anhydride as a source of the acid, and to work out, if practicable, an electrolytic method of separating it from its salts.

The electrolytic method worked very satisfactorily, and led to the further use of this method in the preparation of osmotic membranes. The first results of this investigation are given in an article by Morse and D. W. Horn that appeared in 1901. They say:

> In this connection, it occurred to the authors that if a solution of a copper salt and one of potassium ferrocyanide are separated by a porous wall which is filled with water, and a current is passed from an electrode in the former to another in the latter solution the copper and the ferrocyanogen ions must meet in the interior of the wall and separate as copper ferrocyanide at all points of meeting, so that in the end there should be built up a continuous membrane well supported on either side by the material of the wall. The results of our experiments in this direction appear to have justified the expectation and to be worthy of a brief preliminary notice.

This marks the real beginning of the work on osmotic pressure with which the name of Morse will always be associated. But before the cells were available and therefore before any reliable measurements could be made, years of patient, skillful work were still necessary. Difficulties that seemed insurmountable frequently arose and necessitated new efforts. It must be said that some of us in the laboratory, including myself, at times lost faith in the ultimate success of the work and were perhaps inclined to advise the use of cells that were not perfect. But Morse went steadily on. He had in mind a practically perfect cell that could be used for

[1] To make this story complete it should be added that Morse was the "one of us" here referred to. A piece of glass passed through the tissues of his neck in close proximity to the jugular vein. His escape from death was almost miraculous.

high pressures as well as low. He tried all sorts and conditions of clay and after many, many discouragements he succeeded in finding one and in making a satisfactory glaze quite different from any available, and he achieved success.

In 1902 he and J. C. W. Frazer described "The preparation of cells for the measurement of high osmotic pressures." A careful reading of this article will give some idea of the tremendous difficulties that were met and overcome. The closing paragraph may be advantageously quoted in this connection:

The difficulties of construction are by no means completely overcome, and we have in view a number of changes which we hope will prove of advantage. That these difficulties are of great magnitude will be realized if one considers that in our last experiment the pressure which was measured and which was still below what we were called upon to control would suffice to raise a column of water at 20° to a point 15 meters higher than the top of the Eiffel Tower, or which would raise from its base a marble shaft whose height is 120 meters. These comparisons will perhaps make it clear that the most painstaking attention to every detail of construction is absolutely essential to success when an apparatus like ours is to be made up of several parts, consisting of different materials, and which must be united without the usual mechanical means of securing strong joints.

Soon after this the Carnegie Institution of Washington lent its powerful aid to the large investigation thus begun. In 1914 the institution published a memoir entitled "The Osmotic Pressure of Aqueous Solutions: Report on Investigations made in the Chemical Laboratory of the Johns Hopkins University during the years 1899–1913. By H. N. Morse." In it is given a detailed account of this remarkable piece of experimental work. Anyone who reads it understandingly will recognize that no one but a master of experiment could have done this. The work required the highest degree of resourcefulness and skill, of patience and persistence. Anyone of ordinary caliber would have stopped short of the accomplishment. Morse was not satisfied with anything but perfection as nearly as this could be reached, and as it never can be reached, he worried about the residual, no matter how small it might be. In the concluding chapter of the Carnegie memoir occur these words:

The work reported upon in the preceding chapters is only a fraction of the task which the author hopes to accomplish, or to see accomplished by others. The investigation—already 15 years old—was undertaken, in the first instance, with a veiw to developing a practicable and fairly precise method for the direct measurement of the osmotic pressure of aqueous solutions. The need of such a method for the investigation of solutions seemed to the author very great and very urgent.

Honors came to him rather late, but they came; the chief among these was the award of the Avogadro medal of the Turin Academy of Sciences, in 1916.

In 1911 an international congress of scientists assembled at Turin, Italy, to celebrate the centennial of the announcement of the hypothesis of Avogadro. Those in attendance decided to award a medal to be known as the Avogadro medal. This medal was to be awarded to the investigator who should, in the judgment of the awarding committee, make the most valuable contribution to the subject of molecular physics during the years 1912, 1913, and 1914.

A few words in regard to Morse, the man. He was quiet and uneffusive. He did not care for the ordinary intercourse with his fellowmen. He lived, when not in the laboratory, for his family and a few kindred spirits. He married twice and had four children—a daughter and three sons. His second wife, who was Miss Elizabeth Dennis Clarke, of Portland, Me., his daughter, and two sons survive him. In his later years his wife was of great assistance to him in preparing his articles for publication and was a true helpmate in every way.

For many years he spent his summers at Chebeague, in the beautiful Casco Bay. Here he had a simple comfortable cottage and garden. He delighted to work, both in and out of the house, and this gave him his exercise. He was rather stout and he knew that he needed exercise to keep his weight down. He therefore indulged in walking, bicycling, and finally in motoring, and he managed to keep fairly well. But after his retirement in 1916 his health failed. His strength gave out and his courage also. He did not dare to take his car out of the garage, and his walks were very short. I saw him in May, just before he went to Maine, and thought he seemed more like his old self. He even talked of taking up his work again. It was not to be. I heard nothing from him after that. And then came the dispatch announcing his rather sudden and entirely unexpected death. He was buried at Amherst, a place that meant so much to him—where he had spent his college years and for some time had had a summer home.

II. PRESIDENT WOODWARD'S ADDRESS

When a man of distinction in science closes his terrestrial career and passes over to one of the older planets, or possibly to one of the hotter stars, of the universe, his demise gives rise, in general, to few reflections and to few regrets. The best that the public can say of him is that he left none of the memories of mischief which constitute what Doctor Johnson called "no desirable fame." But this is because the world at large, learned and unlearned, does not understand him rather than by reason of any disposition to underrate his motives or his achievements. In proportion as his work has been advanced or recondite, it will be difficult to understand, and in about the same proportion the rewards he receives will be mostly posthumous. The unlearned of his contemporaries will call him a "high brow," while the majority of the learned, in our day, at any rate, will call him a "narrow specialist," and let him go at that.

It thus happens that the discoveries and the advances of any age, are, as a rule, adequately understood and utilized only by succeeding ages, and that the originators of such discoveries and advances are oftenest unknown and hence unappreciated except by a very limited number of fellow specialists working in the same or in adjacent fields of research. Not infrequently the pioneer work of these originators is either overlooked, forgotten, or attributed to others. Hence we have patent laws and patent offices to determine priorities and rights in cases of inventions, and medals and prizes and a "Hall of Fame" to bestow belated honors on our eminent contemporaries and predecessors.*

But while these ex post facto devices have the merit of providing means for inductions based on all evidence available, they generally fail to afford the public any adequate recognition either of the nature of the work commended or of the methods by which it was accomplished. Such pioneer achievements are still, even in this enlightened age, commonly attributed not to foresight, industry, persistence, and the utilization of a long line of mistakes and successes of our predecessors, but to the vague discontinuities of supermen and of miraculous conditions. In respect to the real place in civilization to be assigned to constructive thinkers and in respect to the need of such for progress, we have still almost everything to learn. The truth of this apparently dogmatic assertion is well illustrated by the ease with which the populace is now led to entertain the notion that Euclidean geometry and Newtonian dynamics may be displaced summarily by a highly praiseworthy "theory of relativity" whose author makes no pretensions to such revolutionary sentiments.

It is specially fitting at this time, therefore, that your university should hold a conference in commemoration of the life, the character, and the accomplishments of one of her most devoted and most productive investigators. His career exemplifies well the singleness of purpose and the arduous labors essential to progress in the realm of learning in general and in the domain of physical science in particular. He was a typical man of science. His interests, like those of the German chemist, Becher, of the seventeenth century, lay among the "flames and the fumes," and if need be, among the "poisons and the poverty" of the laboratory. Becher lived in an age when chemistry was slowly emerging out of alchemy, but what he said of himself was doubtless often thought, if not said, by Morse and by many of our contemporaries. In his physica subterranea Becher says, "My kingdom is not of this world," referring, of course, to those who would in his day, as in ours, measure everything by the gold standard. And of the alchemists, whose prototypes are still to be reckoned with, he says, "Pseudo-chemists seek gold, but the true philosophers, science, which is more precious than any gold."

Such undoubtedly were the ideals that animated Morse in his career as a chemist, as a teacher, and as an investigator; but he was not a man who would render his ideals or his activities obtrusive in comparison with, or in competition with, the interests of men in other fields of learning. He possessed in high degree that sort of modesty and that sort of reserve which are born of a knowledge of men and things, including especially among the latter the obstinate but constant and determinate properties of matter, with which the chemist and the physicist have more particularly to deal.

Of his vocations as a chemist, as a teacher, and as an investigator, others, who knew him more intimately, are better qualified to speak. My impressions of him were formed, unfortunately for me, during the last 15 years of his life and then only in the capacity of a distant administrator. What impressed me most from the inception of acquaintance with him was his tenacity of purpose. He had a problem to solve and he was willing to go to any extent of time and effort to reach an effective solution. This attitude, it may be remarked, affords one of the surest tests of the productive investigator. He who wanders, or vacillates, or lacks capacity to concentrate attention on a limited range of phenomena, is almost certain to become lost in a maze of futilities. The impression gained of him as a teacher was that he would probably "neglect" his students. But if this was the case, it must have been, as with Rowland and with Mall, a great privilege for the students. To be permitted to "stand around" in the presence of evolving knowledge is the highest opportunity a university can offer and the greatest favor a worthy student may seek. The best teachers are not those who think most for their students, but those who make the students do their own thinking. In the higher work of a university, at any rate, it is essential that the novitiates learn early to use their own heads.

The special work of Morse with which it was my good fortune to become somewhat acquainted was his research on the osmotic pressure, carried on by aid of grants made to him by the Carnegie Institution of Washington. What is called osmose, or osmosis, is a subject beset by technicalities, but its elementary essentials are easily apprehended. When two liquids or gases are separated by a common membrane, there is manifested a tendency to transference from one side to the other through the membrane; and if the liquid or gas to which the transfer takes place is confined, an increase of pressure will result, and this under some circumstances may be not merely appreciable but very great. A homely illustration of osmose and osmotic pressure is afforded in the preparation of cranberry sauce. If osmose is permitted to act, the result will be a good sauce; if osmose is prevented the result will be a bad sauce. Osmose follows slowly if the berries are immersed in a hot solution of sugar; meantime the skins will partake of the general dissolution and become edible with the rest of the gelatinous mass. On the other hand, if the berries are boiled and stirred violently, the well-known inedible product follows.

Briefly stated, the research to which Morse made a capital contribution in this field was that of determining what, for a given membrane and for a determinate range of solutions and of attending temperatures, are the pressures generated. To this research he brought a degree of patience, persistence, and continuity worthy of the highest praise, and by its prosecution to definite conclusions he won for himself a place among the masters in experimental physics. Just as we look with admiration, for example, on the early work in optics of the Arabian physicist and mathematician, Alhazen, so the world will regard with admiration the man who first measured with precision the far more difficult data leading to definite knowledge of osmotic pressures.

All researches best worth while in physical science are beset by obstacles which try the souls of investigators. Most of their time and effort are required, usually, in surmounting these obstacles. This was the case with Morse. He needed a uniform, stable membrane, capable of withstanding repeated pressures of many atmospheres. He was led to use a porous, earthenware cup as a matrix for the electrolytic deposition of metallic salts which furnished the required uniformity of porosity. But it turned out that the potters could not make a cup of sufficiently uniform texture and of sufficient strength to stand the pressures developed. Hence Morse had to apply his science to the art of pottery and learn how to select, to sift, to compress, and to burn clay. This was a task that consumed the greater part of his time for about a decade. But while this was the greatest of his difficulties, it was only one of them. This may suffice here, however, to indicate that the tenacity of purpose already referred to was an indispensable requirement to the success of his project. Baffling and discouraging as was his early experience in this work, Morse never rested until he completed a well-rounded and definite chapter which must be considered the first great classic on the experimental side in the field of osmotics.

It is interesting and instructive to reflect that this field is only one of the numerous fields in the domain of the doctrine of atomism. This doctrine was foreshadowed about 2,000 years ago by the philosophers Leucippus and Democritus and by the poet Lucretius. It has grown astonishingly along with the developments of modern physical science, especially since the advent of the atomic theory of Dalton and the advent of the electrochemical theories of Davy and Faraday. It has now reached the very advanced stage of a complete overthrow of the doctrine of continuous media, a doctrine much alive also 20 centuries ago, and finding its modern Anaxagoras, in this university, in no less a personage than Lord Kelvin, who, as some of you will remember, maintained the continuity of that something we call the ether in his famous "Baltimore lectures" of the year 1884. The structure of matter now seems to have been proved to be plinthoid, and attention is at present concentrated on the individual bricks, the numbers of them per unit volume, and the arrangement of the corpuscles, or subbricks, in them. The contribution of Morse was immediately recognized as a part and parcel of the grand aggregate of evidence in favor of the doctrine of atomism; and it was not a matter of surprise to those acquainted with the subject that the Turin Academy of Sciences awarded him the Avogadro prize on the occasion of the celebration of the one hundredth anniversary of the promulgation of what has since been known as Avogadro's hypothesis, namely, that equal volumes of different gases, subject to the same pressures and temperatures, contain the same numbers of molecules.

The dignified directness, simplicity, and sincerity of Professor Morse were agreeably manifested in the correspondence had with him in reference to his work and its support. He had always a just sense of realities. His enthusiasm and his optimism were always tempered by a recognition of existing conditions and limitations. Although not a professional mathematician, he understood well the meaning and the rigor of the much-neglected rules of arithmetic. His characteristics as a man among men are clearly indicated by himself in the following self-explanatory letter, written in his own plain hand, as were most of his communications—it is dated February 29, 1916:

I have just received from the Accademia delle Scienze di Torino the announcement that the medal provided for at the centennial celebration of the promulgation of Avogadro's Hypothesis, for the best work in molecular physics which should appear in the three following years, i. e., during 1912, 1913, and 1914, has been awarded to my report to the Carnegie Institution on investigations in osmotic pressure.

I hasten to inform you, because I am glad to have justified the confidence you have shown in the work and the liberal support you have given it, without which it would have been impossible for me to have succeeded.

But it should be understood that Morse was not working for medals, or for prizes, or for the approval of learned societies. That the first chapter of his enterprise was completed in time for consideration by the Turin Academy was only a happy coincidence. His zeal and industry were founded in the more enduring sentiments derived from contemplative studies of the properties of matter. He sought to add, and did add, to that sort of knowledge which is verifiable and hence permanently useful to our race. His position in science is therefore secure, for it is written in with the history of the demonstrated constancy of the material phenomena he helped to penetrate, and these phenomena are more enduring than the works of men.

III. PROFESSOR FRAZER'S ADDRESS

My remarks this afternoon are dictated by the intimate association I enjoyed with Professor Morse, extending over a long period of years and covering the time of his greatest scientific productivity. I came to know him as teacher, patient and painstaking, as friend, staunch and self-forgetful, and, lastly, as investigator, resolute and resourceful.

In these circumstances I may be permitted to speak more particularly of the work which has placed the name of Morse so high among the scientists of his time, the work with which his name will always be associated.

Although Professor Morse was primarily an investigator, he devoted long years of his life to routine instruction. His extensive knowledge of the facts of chemistry and his habit of careful individual instruction made the work in his laboratory extremely valuable. The personal contact which he always established with his students, together with his genial disposition and sympathetic attitude, at once established a spirit of friendly cooperation on the part of the student. Most of his students undoubtedly look back on these daily visits in the laboratory as among their most pleasant and profitable experiences while at the university.

When the work on osmotic pressure began Professor Morse was engaged in an extensive investigation on permanganic acid. In the electrolytic method, which he devised for the preparation of this substance, a solution of potassium permanganate was electrolyzed between electrodes separated by a porous clay vessel. At times the pores of this vessel became filled with finely divided manganese dioxide which was formed by the decomposition of the permanganic acid. When in this condition the cells frequently showed slight osmotic activity. This accidental formation of an osmotic cell furnished the idea that the artificial, semipermeable membrane of Traube as used by Pfeffer could be deposited electrically and advantage taken of the great driving force of the electric current to bring up a strong, continuous, semipermeable membrane. Little difficulty was encountered in putting this idea into practice, and in 1901 a brief account of this ingenious method was published.

Subsequent work showed that even such a perfect method for the formation of the membrane could not give a perfect osmotic cell unless the porous clay vessel used for its support was of the required texture. At first it was not believed that the matter of the porous wall would be a difficult part of the problem of making an osmotic cell; it was thought that the production of a suitable porous vessel could be left to the potter, with such instruction as seemed necessary as to what was desired. After an experience of more than a year spent in testing the products of several potteries, it was realized that if solved at all the problem must be taken into the laboratory and a careful scientific study made of the conditions influencing the texture of the product. The efforts of the potter were not, however, complete failures; a few of the first lot of cells submitted, while not perfect, were quite good and served a most valuable purpose, as I shall point out. Up to this time the direct measurement of osmotic pressure of any magnitude was considered an experimental impossibility; but with the best of these cells of the potter a number of measurements were made of the osmotic pressure of sucrose solutions, thus demonstrating the possibilities of direct measurement. Unfortunately all of these cells were broken in attempting to extend the work beyond the strength of the cells to withstand pressure. These first cells of the potter served a second purpose also. By a microscopic study of sections of these cells the desired texture was ascertained, and this information was of considerable aid in directing the course of the experiments when the production of a suitable osmotic cell was made a laboratory problem.

About two years were spent in continuous efforts to produce suitable osmotic cells. At the end of that time it seemed that every possible precaution had been taken to secure success, but failure was the result. But, with the knowledge that the potter had on one occasion succeeded quite well, efforts were continued until encouraging results were obtained; the first stone was loosened and the wall was then easily breached. I shall not attempt to give any of the details of these difficulties. What was constantly in mind during these disappointing years was a perfect osmotic cell; this vision of perfection guided and sustained the efforts in the laboratory until, as in the case of the potter of old, all that was foreseen was either found or created.

After having perfected a method for the deposition of the membrane and worked out in detail the method for the production of a suitable cell, the remaining difficulties, which were largely of a mechanical nature connected with assembling the various parts of the cell, were rather easily overcome. And so, step by step, the obstacles were removed, until after a period of about two years two good cells were finally produced in the laboratory and served to make the first quantitative measurements, and the accumulation of data began. This brief statement will give some idea of the difficult nature of the work. At the present time it requires about three months to get an osmotic cell into measuring condition, and even then it must be given a considerable period of rest between experiments, as it is disastrous to attempt to use a cell too frequently.

Before the work of Professor Morse began, the importance of osmotic pressure had been very generally recognized. Not only in chemistry, where it is of fundamental significance, but also in allied sciences, such as botany and physiology, the importance of osmosis in connection with the motion of the fluids in living tissues was clearly recognized. In fact, its importance in these connections was recognized before its importance to chemistry, and we owe a great deal of the early experimental work on osmotic pressure to investigators working in these fields; but their results were either indirect or covered a very limited range and had little claim to accuracy. So, for years, science had stood before this closed door of knowledge waiting for some one skillful and resourceful enough to gain entrance. This situation left no room to doubt that the one who could succeed in overcoming the experimental difficulties in the way of further progress would perform a valuable service to many branches of science. For this reason one may, at the present time, appraise the scientific contribution of Professor Morse at its true value without any of the uncertainty that so frequently attends the consideration of work so soon after its completion. I shall limit further reference to the importance of this work to chemistry alone, since this was the field of Professor Morse's labors.

The importance of osmotic pressure to chemistry and physics was first pointed out by Van't Hoff in 1885. Van't Hoff showed the quantitative relation that exists between any of the colligative properties of solutions, and these relations and the closely connected theory of electrolytic dissociation of Arrhenius form our present theory of solutions and to a large extent modern theoretical chemistry as well. The introduction of these theories has so completely changed the character of chemical instruction and has been so fruitful in the field of research that it may be truly said that for a large part of the intervening time chemistry has lived upon these ideas. Although the theory of Van't Hoff is based on thermodynamic reasoning, the almost complete lack of experimental evidence on the subject of osmotic pressure so weakened his chain connecting these fundamental properties that many chemists of the older school hesitated to trust it. Briefly, the work of Professor Morse on osmotic pressure was to forge the last link of this chain of experimental evidence and by so doing perform a valuable contribution to theoretical chemistry.

The scientific career of Professor Morse is unusual in that his most important contributions came so late in his life. At the time when others seek to lay aside their burdens and rest, he was striking his most telling blows, and not until his day was far spent and its shadows lengthening did he succeed in completing his chapter of science to his own satisfaction.

This work on osmotic pressure is a model of experimentation which in American research has in some respects a counterpart in the work of Morley on the densities of oxygen and hydrogen. Both are large pieces of experimental research of a fundamental nature extending over many years, both involved overcoming numerous experimental difficulties, and both resulted in giving to the world data of an unexpected excellence.

The work of Professor Morse on osmotic pressure must, therefore, remain one of the brilliant contributions to American chemistry, a precious heritage of our university, an inspiration to those who follow, and a perpetual monument to his memory.

III. DOCTOR HOWELL'S ADDRESS

I had the good fortune to know Doctor Morse with increasing intimacy through many years; from the time that I was a student in his classes in 1880 until his death last summer. My acquaintance with him during this time passed through several stages; the relation of teacher and student, of a friend and colleague, and finally that of a near neighbor for some 20 years during the long pleasant summer vacations—each of these periods gave me a new point of view in regard to his personal qualities; and while I am not qualified to speak as a specialist in reference to his scientific work, it is a pleasure and a privilege to express in a few words my great respect and admiration for him as a man, and my appreciation of the important part that he took in establishing the reputation of this university as a center of scientific research.

My student impressions of him were quickly formed and gauged accurately, I believe; some of them characteristics which made him so eminently successful in his scientific work. The impressions of that period are still very vivid in my memory. I entered one of his classes in quantitative chemical analysis. An enthusiastic young student, I was eager to push ahead as rapidly as possible. When I had repeated a certain method of analysis two or three times I felt that I had got about all there was of value in the procedure and proposed to go on to something new, but my eyes were soon opened to the error of my ways. The big kindly soft-spoken man to whom I reported my work gave me to understand very gently but very firmly that approximate results did not suffice—I was to do the work over and over again until exact and consistent findings were obtained. I recall that upon one occasion, after spending my entire Christmas vacation in a futile attempt to ascertain the composition of a given mineral, all of my tests turning out completely negative, Professor Remsen, in one of his daily walks through the laboratory, was kind enough and indiscreet enough to drop a hint about certain of the rarer metals which finally put me upon the right track. After several experiences of this kind I felt that my position was much the same as that of Peter when he asked how often he should forgive his brother, mentioning seven times as a sort of outside limit. He got the reply, you will remember, that if necessary he must forgive seventy times seven. That was about the kind of admonition that I received from Professor Morse. Then and later I found that accuracy and thoroughness were the underlying principles of his nature and the principles which he most sought to inculcate in his students. Neither trouble nor time weighed much in the balance against these virtues, and certainly he did not spare himself or his pupils in his effort to obtain the greatest possible perfection in methods and in results. Difficulties did not discourage him, in fact it seemed to me that they rather attracted than repelled him; for gentle as he was in mood and in manner, there was nothing soft or yielding in his character. Determination and inflexibility of purpose were among his conspicuous qualities, and his colleagues know well how greatly these characteristics served him in the difficult problems that he undertook to solve. It is probable that as a teacher he was not especially well suited to the average student. He did not possess or had not cultivated that specious art of beguiling the careless or indifferent student into a love for his subject. His methods were sober and serious, and for those who were in earnest and had a definite end in view he was a great teacher. They got from him the kind of training that leaves a permanent impression throughout life. This is the testimony that I have heard from not a few of his students who have since achieved distinction as scientific workers. He was a teacher for the few, not for the many, and those pupils of his who afterwards became investigators themselves will always cherish a grateful remembrance of the benefits they derived from his example and his instruction. When I came to know Doctor Morse as a colleague I had frequent opportunities to discuss with him general scientific questions and educational policies, especially as they affected this university. The dominant impression that I recall from these conversations is his high ideals in regard to scientific research. He had much of the common sense and practical ingenuity which we are accustomed to consider as inherent in the New England stock. But long and close association with university life had developed a sincere appreciation of the value of fundamental work in science. He had absorbed, and to an important extent had helped to create, that fine spirit of research which was the chief glory and distinction of the university. It is not easy to describe this spirit in words. All research that is sincere and well planned is good and useful, whether its purpose is to discover new truths or to devise methods of applying knowledge to the benefit of mankind. But there is one glory of the sun, and another glory of the moon, and every one must admit, I believe, that in this matter of research the greater glory belongs to him who pursues knowledge for knowledge's sake. Unless this spirit is in a man he is not fitted for the higher and more difficult tasks of discovery. And just because research of this kind is not valued by the majority, it is important that the few who realize its worth shall be steadfast in its support. This was Doctor Morse's attitude. He did not of course undervalue utilitarian investigations; on the contrary, he placed a great value upon them as any sensible person must do, but his point of view was that the more fundamental research which serves to advance our theoretical knowledge is the kind that should be especially fostered in a university.

Toward the end of his life he showed some signs of discouragement with existing conditions in the universities. So much so, in fact, that he was inclined to advise his young men to seek positions in the industrial laboratories rather than in the universities. I am not sure that I understood fully his reasons for taking this somewhat paradoxical attitude. Possibly it was of the nature of a protest against what he considered the inadequate opportunities and compensation offered to young men in the universities; possibly he felt, with some others, that the industrial and special laboratories, in some subjects at least, are offering the best opportunities in theoretical as well as practical research, and that young men of ambition and promise may look to them with more confidence for that substantial support and encouragement which work of this kind must have to insure its proper development.

The good chance that made me his neighbor for many years on an island on the coast of Maine during the summer vacations gave me abundant opportunities to discover and to appreciate his many sterling and lovable personal characteristics. I found that beneath his quiet and somewhat stern exterior there was a warm heart, an active emotional nature, and a great love of humor. Those whose acquaintance with Doctor Morse was only incidental or official must have gained the impression that he was an extremely reserved man. In a general gathering he had little to say as a rule. The rapid-fire exchange of question and comment did not suit his deliberate temperament, and he was likely under such conditions to remain in the background as a quiet listener. But in a small company of intimates he could be a most delightful companion, both entertaining and instructive. On suitable occasions he had many good stories to tell, dealing mostly with the human frailties of the older natives of the island. The point of the story was always brought out with a reminiscent chuckle or a good hearty laugh which showed his own enjoyment in the recollection, and expressed also perhaps his sympathetic realization of those touches of nature that make us humans all akin. When the conversation turned upon more serious topics he displayed a remarkable fund of accurate information gathered from his wide experience and extensive reading. When others guessed or spoke vaguely and uncertainly, he was sure to have some precise and authentic knowledge. His interest in matters pertaining to the progress and welfare of the country, especially in political and social affairs, was real and warm. They were not for him simply matters of reason and judgment, they penetrated deep into his emotional nature. While his manner and mode of expression were judicial and conveyed the impression of a coldly rational temperament, experience led me to realize that beneath the surface there was that kind of emotional heat that makes a loyal partisan. He was a man who took sides on important questions, and once he had made up his mind he could maintain his position with a granitelike firmness against which arguments had little effect. In our estimates of men and affairs we differed sometimes toto caelo, and in the discussions that ensued I rarely had the satisfaction of seeing any of my chance arguments penetrate the joints of his armor. But it is a pleasure to remember that our discussions never became heated or bitter, for he knew how to differ in his opinion in a courteous and considerate manner. It was in fact a great pleasure and inspiration to talk matters over with him, whether we agreed or disagreed, because of the fine and sturdy patriotism he exhibited under all circumstances. His scientific interests did not prevent him from following minutely all the movements and tendencies of the times, and I was often surprised to find in place of the ultraconservatism that one might have expected to encounter in a man of his type, a marked degree of modernism. So far as his country and his science were concerned, he was always on the side of expansion and progress.

Outside his reading his main occupation and recreation in summer was the care of his garden. Into this work and play, for it was both to him, he carried the same spirit of unusual thoroughness that was so characteristic of his scientific experiments. His materials and tools must be of the best quality and all the processes of leveling, weeding, planting, and transplanting were carried out with a degree of perfection that excited general comment in our small neighborhood. It was well understood in that locality that anyone who did work for him was expected to measure up to a very high standard of performance. No matter how small the undertaking, it was planned with a singular degree of completeness, for he cordially disliked anything of the nature of a makeshift or a temporary expedient. Nature was not always kind to his agricultural experiments. Between the rigors of the climate and unexpected acts of

Providence they encountered many serious setbacks, but in this case, as in his scientific work, opposition and misfortune served simply to stimulate him to renewed effort. If one scheme failed he devised another more complete, and usually, so it seemed to me, more difficult of performance. Temporary failures seemed to act as challenges to his resourcefulness and determination, and I am confident that he experienced a real joy in those contests with nature.

Science needs for its continued progress talents of many kinds, insight and inventiveness, enthusiasm, wide knowledge, a high degree of experimental skill, and many other of the best qualities, but perhaps no gifts are more essential than exactness and thoroughness. Through them advancement is made certain; few backward steps must be taken. It was in these qualities that Doctor Morse was preeminent. The work that he did was exceedingly well done, so that other men might build upon it with confidence. By the exercise of these talents he was able to contribute to the science of chemistry knowledge of lasting value, and it is pleasant to remember that for this work he received the highest reward that a scientist can hope to obtain—I mean the sincere gratitude and applause of his fellow specialists

APPENDIX

INVESTIGATIONS CARRIED OUT UNDER THE DIRECTION OF H. N. MORSE

MORSE, H. N. Ueber eine neue Darstellungsmethode der Acetylamidophenole. Ber. d. chem. Gesell., **11**, 232 (1878).

——— On the determination of barium as chromate. Amer. Chem. Journ., **2**, 176 (1880).

MORSE, H. N., and DAY, W. C. Determination of chromium in chrome iron ore. Amer. Chem. Journ., **3**, 163, (1881).

MORSE, H. N., and BAYLEY, W. S. Haydenite. Amer. Chem. Journ., **6**, 24 (1884).

MORSE, H. N., and KEISER, E. H. A simple apparatus which enables students to determine the equivalents of certain elements. Amer. Chem. Journ., **6**, 347 (1884).

MORSE, H. N. A method of determining the value of zinc dust. Amer. Chem. Journ., **7**, 52 (1885).

——— Two forms of apparatus which facilitate the correct reading of gas volumes over water. Amer. Chem. Journ., **7**, 58 (1885).

——— An apparatus for the purification of mercury by distillation in a vacuum. Amer. Chem. Journ., **7**, 60 (1885).

MORSE, H. N., and BURTON, W. M. A method for the determination of butter in milk. Amer. Chem. Journ., **8**, 222 (1886).

MORSE, H. N., and LINN, A. F. The determination of nitric acid by the absorption of nitric oxide in a standard solution of permanganate of potassium Amer. Chem. Journ., **8**, 274 (1886).

MORSE, H. N., and PIGGOT, C. A method for the determination of butter in milk. Amer. Chem. Journ., **9**, 108 (1887).

MORSE, H. N., and BURTON, W. M. On the supposed dissociation of zinc oxide and the condition of the atmosphere within a platinum vessel heated by a gas flame. Amer. Chem. Journ., **10**, 148 (1888).

——— A method for the separation and determination of boric acid. Amer. Chem. Journ., **10**, 154 (1888).

——— The atomic weight of zinc as determined by the composition of the oxide. Amer. Chem. Journ., **10**, 311 (1888).

——— The removal of iodate from the iodide of potassium by means of zinc amalgam. Amer. Chem. Journ., **10**, 321 (1888).

——— A method for the analysis of butter, oleomargarine, etc. Amer. Chem. Journ., **10**, 322 (1888).

MORSE, H. N., and WHITE, J., Jr. The dissociation of the oxides of zinc and cadmium in the vapors of their respective metals. Amer. Chem. Journ., **11**, 258 (1889).

——— The dissociation of the sulphides of cadmium and zinc by means of metallic cadmium and zinc. Amer. Chem. Journ., **11**, 348 (1889).

MORSE, H. N., and JONES, H. C. On the action of metallic cadmium on the halogen salts of cadmium, and on the sub-hydroxide and sub-oxide of cadmium. Amer. Chem. Journ., **12**, 488 (1890).

MORSE, H. N., and WHITE, J., Jr. The dissociation of magnesium oxide by means of metallic magnesium. Amer. Chem. Journ., **13**, 128 (1891).

MORSE, H. N., and JONES, H. C. A redetermination of the atomic weight of cadmium. Amer. Chem. Journ., **14**, 261 (1892).

MORSE, H. N., and WHITE, J., Jr. The transportation of solids in a vacuum by the vapors of metals. Amer. Chem. Journ., **14**, 314 (1892).

MORSE, H. N., and BLALOCK, T. L. Instruments for the graduation and calibration of volumetric apparatus. Amer. Chem. Journ., **16**, 479 (1894).

MORSE, H. N., and CHAMBERS, A. D. A method for the standardization of potassium permanganate and sulphuric acid. Amer. Chem. Journ., **18**, 236 (1896).

MORSE, H. N., HOPKINS, A. J., and WALKER, M. S. The reduction of permanganic acid by manganese dioxide Amer. Chem. Journ., **18**, 401 (1896).

MORSE, H. N., and ARBUCKLE, H. B. A redetermination of the atomic weight of zinc. Amer. Chem. Journ., **20**, 195 (1898).

MORSE, H. N., and REESE, C. L. A reduction of permanganic acid by manganese peroxide. Amer. Chem. Journ., **20**, 521 (1898).

MORSE, H. N., and ARBUCKLE, H. B. The atomic weight of cadmium. Amer. Chem. Journ., **20**, 536 (1898).

MORSE, H. N., and BYERS, H. G. On the cause of the evolution of oxygen when oxidizable gases are absorbed by permanganic acid. Amer. Chem. Journ., **23**, 313 (1900).

MORSE, H. N., and OLSEN, J. C. Permanganic acid by electrolysis. Amer. Chem. Journ., **23**, 431 (1900).

MORSE, H. N., and HORN, D. W. The action of carbon dioxide on the borates of barium. Amer. Chem. Journ., **24**, 105 (1900).

MORSE, H. N., and HORN, D. W. Preparation of osmotic membranes by electrolysis. Amer. Chem. Journ., **26,** 80 (1901).

MORSE, H. N., and FRAZER, J. C. W. The preparation of cells for the measurement of high osmotic pressures. Amer. Chem. Journ., **28,** 1 (1902).

MORSE, H. N. New osmotic membranes prepared by the electrolytic process. Amer. Chem. Journ., **29,** 173 (1903).

MORSE, H. N., and FRAZER, J. C. W. A new electric furnace and various other electric heating appliances for laboratory use. Amer. Chem. Journ., **32,** 93 (1904).

MORSE, H. N., and TAYLOR, L. S. An electrical method for the combustion of organic compounds. Amer. Chem. Journ., **33,** 591 (1905).

MORSE, H. N., and FRAZER, J. C. W. The osmotic pressure and freezing-points of solutions of cane sugar. Amer. Chem. Journ., **34,** 1 (1905).

MORSE, H. N., and GRAY, C. W. An electrical method for the simultaneous determination of hydrogen, carbon and sulphur in organic compounds. Amer. Chem. Journ., **35,** 451 (1906).

MORSE, H. N., FRAZER, J. C. W., and HOPKINS, B. S. The osmotic pressure and depression of the freezing-points of solutions of glucose. Amer. Chem. Journ., **36,** 1 (1906).

MORSE, H. N., FRAZER, J. C. W., HOFFMAN, E. J., and KENNON, W. L. A redetermination of the osmotic pressure and depression of the freezing-points of cane sugar solutions. Amer. Chem. Journ., **36,** 39 (1906).

MORSE, H. N., FRAZER, J. C. W., and LOVELACE, B. F. The osmotic pressure and the depression of the freezing-points of solutions of glucose. Amer. Chem. Journ., **37,** 324 (1907).

MORSE, H. N., FRAZER, J. C. W., and HOLLAND, W. W. The osmotic pressure of cane sugar solutions in the vicinity of the freezing-point of water. Amer. Chem. Journ., **37,** 425 (1907).

MORSE, H. N., FRAZER, J. C. W., and ROGERS, F. M. The osmotic pressure of glucose solutions in the vicinity of the freezing-point of water. Amer. Chem. Journ., **37,** 558 (1907).

MORSE, H. N., FRAZER, J. C. W., and DUNBAR, P. B. The osmotic pressure of cane sugar solutions in the vicinity of 5°. Amer. Chem. Journ., **38,** 175 (1907).

MORSE, H. N., and MORSE, H. V. The osmotic pressure of cane sugar solutions at 10°. Amer. Chem. Journ., **39,** 667 (1908).

MORSE, H. N., and HOLLAND, W. W. The osmotic pressure of glucose solutions at 10°. Amer. Chem. Journ., **40,** 1 (1908).

MORSE, H. N., and MEARS, B. The osmotic pressure of cane sugar solutions at 15°. Amer. Chem. Journ., **40,** 194 (1908).

——— Improvement in cells for the measurement of osmotic pressure. Amer. Chem. Journ., **40,** 266 (1908).

MORSE, H. N., and LOVELACE, B. F. Improvements in manometers for the measurement of osmotic pressure. Amer. Chem. Journ., **40,** 325 (1908).

MORSE, H. N., and HOLLAND, W. W. The osmotic pressure of cane sugar solutions at 25°. Amer. Chem. Journ., **41,** 1 (1909).

——— The regulation of temperature in the measurement of osmotic pressure. Amer. Chem. Journ., **41,** 92 (1909).

——— The osmotic pressure of cane sugar solutions at 20°. Amer. Chem. Journ., **41,** 257 (1909).

MORSE, H. N., HOLLAND, W. W., FRAZER, J. C. W., and MEARS, B. The relation of osmotic pressure to temperature, Part I. Amer. Chem. Journ., **45,** 91 (1911).

MORSE, H. N., HOLLAND, W. W., and CARPENTER, J. L. The relation of osmotic pressure to temperature, Part II. Amer. Chem. Journ., **45,** 237 (1911).

MORSE, H. N., HOLLAND, W. W., and ZIES, E. G. The relation of osmotic pressure to temperature, Part III. Amer. Chem. Journ., **45,** 383 (1911).

MORSE, H. N., HOLLAND, W. W., and MYERS, C. N. The relation of osmotic pressure to temperature, Part IV. Amer. Chem. Journ., **45,** 517 (1911).

MORSE, H. N., HOLLAND, W. W., ZIES, E. G., MYERS, C. N., CLARK, W. M., and GILL, E. E. The relation of osmotic pressure to temperature, Part V. Amer. Chem. Journ., **45,** 554 (1911).

MORSE, H. N., HOLLAND, W. W., MYERS, C. N., CASH, G., and ZINN, J. B. The osmotic pressure of cane sugar solutions at high temperatures. Amer. Chem. Journ., **48,** 29 (1912).

BOOKS

MORSE, H. N. Exercise in quantitative chemistry. Boston: Ginn & Co. (1905).

——— The osmotic pressure of aqueous solutions. Report on investigations made in the chemical laboratory of the Johns Hopkins University during the years 1899–1913. Monograph published by the Carnegie Institution of Washington, No. 198 (1914).