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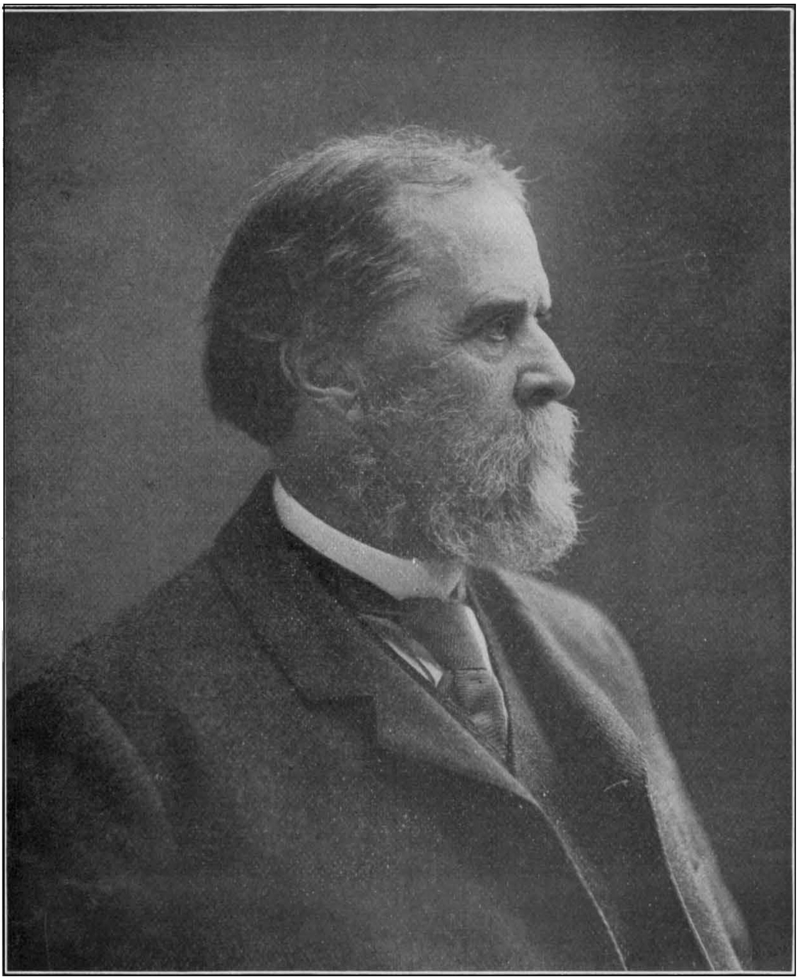

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Wolcott Gibbs

WOLCOTT GIBBS.*

Oliver Wolcott Gibbs,† a charter member of the National Academy of Sciences, and at one time its president, was born in the city of New York, February 21, 1822. His father, Colonel George Gibbs, was a man of some wealth, who owned a large country place at Sunswick, on Long Island, not far from the then small metropolis. He was an enthusiastic mineralogist, and gathered a collection which, ultimately sold to Yale College, became the nucleus of the great cabinet since made famous by the labors of the two Danas, Brush, and Penfield. It was perhaps the control of the Gibbs collection which first led J. D. Dana to write his classical "System of Mineralogy." Colonel Gibbs, for whom the mineral *gibbsite* was named, was himself the author of several memoirs upon mineralogical subjects; and his oldest son, also named George, achieved some reputation as a geologist and as a student of ethnology. Wolcott Gibbs was born into an atmosphere of scientific interests, and his early associations must have influenced his choice of a career. A taste for science ran in the family.

Laura Gibbs, the mother of Wolcott, came of distinguished ancestry. Her father, Oliver Wolcott, rose through various positions to that of Secretary of the United States Treasury; a post which he held during the latter part of Washington's administration and well into the administration following. He then became a justice of the United States Circuit Court, and during the last ten years of his life he was Governor of the State of Connecticut. His father, another Oliver, was a magistrate, a major general of militia, a member of Congress, and a signer of the American Declaration of Independence. He too was a Governor of Connecticut, and so also was his father, Roger Wolcott, the first noteworthy member of the line. In

* Read before the National Academy of Sciences, November, 1909.

† He dropped the Oliver early in his career.

short, the ancestors of Wolcott Gibbs were people of far more than average ability, who had the confidence and esteem of their fellow-citizens, and were therefore entrusted with positions of high rank and responsibility. Even though there was no commanding genius among them, no man of world-wide fame, they at least left to their descendants a legacy of lofty examples, well worthy of emulation. We may differ in our opinions as to the significance of heredity; but we can recognize the fact that Gibbs received from his forbears a sound mind in a sound body, together with traditions of well doing that could not be disregarded. A good ancestry is a good beginning for any man.

In his early environment Gibbs was also fortunate. Although he was only eleven years old when he lost his father, his mother survived for many years, and gave him the best of opportunities for healthy development. She was a woman of strong character and unusual ability, and her home became a center in which the best intellectual society of New York was to be found. Her character, forceful, positive, patriotic, and public spirited, was reflected in that of her son.

The early childhood of Wolcott Gibbs was largely spent at his father's estate of Sunswick, where, as he tells us in a brief autobiographical note, "he was often occupied with making volcanoes with such materials as he could obtain, and in searching the stone walls . . . for minerals, and the gardens and fields for flowers." At the age of seven he was sent to a private school in Boston, where he was under the care of a maiden aunt, whose sister had married the famous Unitarian divine, William Ellery Channing. The winters were passed in Boston, and the summers with the Channings at their country place near Newport, Rhode Island. Here again he was surrounded by choice influences, and saw many distinguished people. The reputation of Dr. Channing attracted many visitors, including more than a few from abroad, and the boy must have come to some extent in contact with them. Being but a child, he may not have understood or appreciated his opportunities, but his imagination could not have been entirely unaffected. His early associations foreshadowed his later career.

When he was twelve years old, Gibbs returned to New York, and began his preparation for college. In 1837 he entered Columbia College as a freshman, and graduated in 1841. It was in his junior year that he published his first scientific paper, a description of a new form of galvanic battery, in which carbon was used, probably for the first time, as the inactive plate. This achievement, unimportant as it may seem now, was really remarkable in two ways; first, on account of the youth of the author, and secondly, because of the conditions under which the work was done. In those days the American colleges, like the public schools of England, were intensely classical in their aims, and science received the minimum of attention. Latin, Greek, and mathematics ruled the curriculum, with only a smattering of other subjects. Even in the classics literature was subordinate to grammar, and as for the modern languages they were almost if not quite ignored. What science was taught was taught by lectures and text-book recitations, for the era of laboratory instruction had not begun. That a pupil of eighteen should make an original investigation under such conditions was surprising, but it showed the irresistible tendencies at work in his mind. The early impulses, received from his father, could not be overcome.

After receiving his bachelor's degree young Gibbs went to Philadelphia, where he served as assistant in the laboratory of Robert Hare, the well-known inventor of the compound blowpipe, who was then Professor of Chemistry in the Medical School of the University of Pennsylvania. Gibbs' purpose was to fit himself for holding a similar professorship, and so, after several months of experience with Hare, he entered the College of Physicians and Surgeons in New York, and in 1845 became a full-fledged Doctor of Medicine. He never practiced, and probably never intended to do so, for the study of chemistry was the main purpose of his life, and his medical studies were only a means to an end. Indeed, they stood him in good stead when, many years later, in collaboration with Drs. Hare and Reichert, he undertook to study the physiological effects of definitely related chemical compounds on animals.

Up to this point the training of the future chemist had been only preliminary, a laying of foundations, so to speak. In his time advanced scientific education was not easily obtained in America, and ambitious students who were able to do so sought their higher opportunities in Germany. Accordingly, Doctor Gibbs, as we must now call him, went abroad, and began by spending several months with Rammelsberg in Berlin. After this he studied for a year under Heinrich Rose, which was followed by a semester with Liebig at Giessen. He next went to Paris, where he attended lectures by Laurent, Dumas, and Regnault, and in 1848 he returned home, ready to begin the real labors of his life. Among his teachers the one who most impressed him was Rose, whom Gibbs greatly admired, and who doubtless gave his pupil his strong bias towards analytical and inorganic chemistry. From his other teachers, however, Gibbs acquired a breadth of view and an insight into different fields of research, which made him all the stronger as an investigator. He was a chemist in the largest sense of the term, and not a mere sub-specialist.

After returning to America, Gibbs first delivered a short course of lectures at Newark College, in Delaware. Then, in 1849, his native city claimed his services, and he was appointed professor of chemistry in the newly established Free Academy, now the College of the City of New York. He remained in this position for fourteen years, chiefly occupied in teaching elementary students, and at first doing, apparently, little else. He was not idle by any means, but he was finding himself, and his time was not wasted. It was in 1857 that his first really notable research was given to the world, namely, the joint memoir of Gibbs and Genth on the ammonio-cobalt bases. Of this I shall speak more at length later. In 1851 he became an associate editor of the American Journal of Science, and began the preparation of a series of abstracts which brought the results of foreign investigations to the attention of American readers. These abstracts amounted in all to about 500 pages, and were, despite their brevity, conspicuously clear and comprehensive. In 1861 the first of his papers upon the platinum metals appeared, and his reputation was at last firmly established.

Notwithstanding his recognized ability, Doctor Gibbs, during this period, suffered one serious disappointment. The chair of chemistry in his *alma mater,* Columbia College, became vacant, and Gibbs, backed by the recommendations of nearly all the leading men of science in America, was a candidate for the position. On very questionable grounds his candidacy was rejected, and a man of smaller attainments received the appointment. This was unfortunate for Columbia, but not altogether so for Gibbs. In 1863 he was called to a very desirable post, the Rumford Professorship in Harvard University. Nominally, this was a professorship of the "Application of Science to the Useful Arts," but its incumbent, in addition to lecturing upon heat and light, was expected to take charge of the chemical laboratory in the Lawrence Scientific School, and this gave Gibbs a great opportunity for usefulness. Furthermore, the position was a delightful one upon its social side, and he was thrown into close association with many congenial spirits. There were Louis Agassiz the zoologist, Asa Gray the botanist, Jeffries Wyman in comparative anatomy, Benjamin Pierce in mathematics, and J. P. Cooke in chemistry. Literature was represented by Longfellow, Lowell, Holmes, and other less famous writers; altogether an aggregation of distinguished men which could not be matched elsewhere in America and equalled at few places in the world. Gibbs was among his peers, and in a place where his worth could be fully appreciated.

Doctor Gibbs remained in charge of the Scientific School laboratory for eight years, and during that time his researches were for the great part, although not exclusively, devoted to analytical methods. The school was technically a department of Harvard University, and yet its work was carried on quite independently. The students were usually men of definite purposes, who knew what they wanted and went where it could be best obtained. They went to Agassiz for zoology, to Gray for botany, and to Gibbs for chemistry, because those men were the leaders in their respective subjects, and they worked, not in classes, but as individuals. The students in chemistry had little or nothing to do with the students in other branches, for the school was distinctly professional in its aims. Teachers from other institutions, seeking to enlarge their knowledge, were often among them. Gibbs was now training men who intended to become chemists, and some of them were qualified to assist in his investigations. Moreover, he was not overloaded by numbers, for he rarely had more than twenty students in attendance at any one time. There was one assistant, to relieve him of routine work; his lectures upon light and heat cost him little effort, and he was therefore able to devote his energies to research more advantageously than ever before.

It was my good fortune to have been a student under Gibbs during the greater part of four years, between 1865 and 1870. I may therefore be permitted to speak of his teaching from my own experience, believing that in such matters the personal note is not without value. There was nothing unusual about the course of instruction so far as ordinary details went, for that necessarily followed certain well established lines. Most of the students had already gained some elementary knowledge of chemistry; their work began with the usual practice in analytical methods and chemical manipulations, and as the men showed capacity they were admitted to the confidence of their master and aided him in his investigations. This procedure may seem commonplace enough today, but in the years of which I speak it was new to American institutions, and was looked upon doubtfully by some of the old-fashioned pedagogues. The students who chose to do so attended the chemical lectures of Cooke in Harvard College, but that work was wholly optional. The only formal examination was the final examination for the bachelor's degree, and therefore there was little or no cramming. Gibbs apparently believed, although his belief was not stated in set terms, that a good teacher who kept in touch with his pupils should know perfectly well where they stood, and no examination could tell him anything more. In fact, examinations are often misleading, for the reason that even a fine scholar of nervous temperament may become confused and helpless during the ordeal, and fail to answer the simplest questions. On the other hand a poor student with a fair memory may cram for an examination, pass triumphantly, and amount to nothing afterwards. The real examinations under Gibbs were daily interviews, when he visited each student at his laboratory table and questioned him about his work. This, together with the reported analyses, gave the teacher a clear conception of the true standing of each man. The fewness of the pupils was a distinct advantage, for all worked together in one room, beginners and research students often side by side. The result was that they learned much from one another, and there were many discussions among them over the burning problems of the day. The men were taught to stand on their own feet, and to think for themselves, laying thereby a foundation for professional success which was pretty substantial. The course of instruction had no definite term of years prescribed for it, and graduation came whenever the individual had done the required amount of work and submitted an acceptable original thesis. The final examination was usually oral, each man alone with his master, and was conducted in an easy conversational way which tended to establish the confidence of the candidate from the very beginning. In my own case, I remember that the questions covered a fairly broad range of chemical topics, and at the end of it Doctor Gibbs drew me into a sort of discussion or argument with him over the then modern doctrine of valency. I now see that his purpose was not merely to ascertain what I had read on the subject, but what I really thought about it, if indeed I was entitled to think at all. Gibbs invariably treated his students, not as so many vessels into which knowledge was to be poured, but as reasonable beings, with definite purposes, to whom his help must be given. That help was never denied to any man who showed himself at all worthy of it. The research work in which the advanced students shared, and for which they received public credit, served to teach them that chemistry was a living and growing subject, and to train them in the art of solving unsolved problems. They were taught to *do,* and encouraged to *think,* and if, on going forth into the world, they sometimes felt themselves qualified to revolutionize all science, their vanity did no harm and was soon remedied. An enlightened ignorance is only gained with advancing years, and the enthusiastic beginner cannot be expected to appreciate it. It is the last polish that the ripened scholar acquires.

What now is the meaning of this long disquisition upon the methods of Gibbs Laboratory? What was there at all unusual in his teaching? Nothing, perhaps, from a modern point of view, but much that was new to America in the middle sixties. It was Gibbs' peculiar merit that he, more than any other one man, introduced into the United States the German conception of research as a means of chemical instruction, a conception which is now taken as a matter of course without thought of its origin. Gibbs worked with small resources and no help from outside; he was a reformer who never preached reform; his students rarely suspected that they were doing anything out of the ordinary; but they had the utmost confidence in their master, and took it for granted that his methods were sound. There was nothing of the drill master about Gibbs, no trace of pedantry, no ostentation of profound learning; but the students never doubted his sincerity of purpose and interest in their work, or questioned his ability as a teacher. As for Gibbs himself, it is doubtful whether he ever imagined that his teaching was at all remarkable. He did what was to him the natural and obvious thing to do, simply and without pretense, and the results justified his policy. The success of his students is perhaps the best monument to his memory.

In 1871 the chemical instruction at Harvard University was reorganized, in spite of strong protests from Gibbs and other scientific leaders. The laboratory of the Scientific School was consolidated with that of the College, and Gibbs had no more students in chemistry. His work was limited to that of the Rumford professorship—a change which left him more time for personal research, but took from the students the inspiration of his teaching. The change may have been justifiable on grounds of economy, but it was otherwise a mistake, and it was so recognized among chemists generally. The economy was only financial; but an important asset of the University, the ability of a great teacher, was not turned to the best account. Fortunately for Gibbs he had independent means, although he was not a rich man, and he was able to equip a small laboratory of his own and to employ a private assistant. In that laboratory he carried out those brilliant researches upon the complex inorganic acids, which marked the culmination of his career. The equipment was most modest, and in some respects it reminded one of the famous kitchen of Berzelius. Indeed, Gibbs' favorite piece of apparatus was that homely utensil, a cast iron cooking stove, which served for several useful purposes. Precipitates could be dried in the oven, crucibles were buried in the coals, water was kept hot on top of it. As an instrument of research it was neither elegant nor orthodox, but it did the work, and what more could be desired? Gibbs adapted himself to circumstances, and cared little for the instrumental refinements which so many chemists seem to regard as necessary. The real essentials were provided; mere conveniences, the luxuries of research, he could do without.

For sixteen years after the closing of the Scientific School laboratory, Doctor Gibbs lectured to small classes of students upon the spectroscope and on thermodynamics. In 1887 he retired, as Professor Emeritus, and went to live in his house at Newport, where he had been accustomed to spend his summer vacations. His private laboratory was moved to Newport also, and there he continued his investigations until, enfeebled by old age, he was obliged to rest on his laurels. As a recreation he cultivated a flower garden, and was proudest of his roses. In that way his love of the beautiful found its chief expression. On December 9, 1908, he passed away, at the age of nearly 87. His wife, whose maiden name was Josephine Mauran, and whom he had married in 1853, died several years earlier, leaving no children.

So much for biography. It now remains for us to consider the contributions of Gibbs to science, and to trace their relations, so far as may be practicable, to later work. An investigation never stands alone; each one touches other investigations at several points; and its worth may be greatest as the progenitor of other researches. The suggestiveness of a discovery, its influence in stimulating thought, is fully as important as its immediate outcome. It is a seed, whose value is finally determined by its fertility.

Gibbs' first paper, a "Description of a new form of magneto-electric machine, and an account of a carbon battery of considerable energy," published when he was a junior student at Columbia, has already been mentioned. In 1844 he attempted to discuss the theory of compound salt radicles, and in 1847, while a student abroad, he published a number of mineral analyses. In 1850 Gibbs pointed out the interesting fact that compounds which change color when heated, do so in the direction of the red end of the spectrum. In 1852 he published the first of his memoirs upon analytical methods, in which he proposed the separation of manganese from zinc by means of lead peroxide; and in 1853 he prepared, and partially described, an arsenical derivative of valeric acid. In all of this work there was nothing of great importance, but its varied character is suggestive. It represents the efforts of an active mind, feeling its way under unfavorable conditions, and not quite sure of its true capacities. Mineral chemistry, organic chemistry, analytical chemistry, chemical theory, and physics in turn attracted his attention during this formative period of his career. It was in the great research upon the ammonio-cobalt bases that Gibbs finally found himself and forced the world to recognize his ability. His apprenticeship was ended, and his work as a master had begun.

The first of the ammonio-cobalt compounds, the oxalate of luteocobalt, was prepared by Gmelin in 1822, the very year in which Gibbs was born. It was supposed, however, to be a salt, of cobaltic acid, and several other chemists, who studied it later, shared in the same misapprehension. In 1847, Genth, then at Marburg, discovered other salts of these bases, but it was not until 1851, after his emigration to America, that he published his description of them in a rather obscure journal. Genth was the first to recognize the true character of the new compounds, and he was followed by Claudet and Fremy, the three chemists working independently of one another and almost simultaneously. Up to this point Fremy's work was the most exhaustive, but it left much to be desired.

Genth had identified the two bases since known as luteocobalt and roseocobalt. In 1852 Gibbs discovered the salts of xanthocobalt, which contained, in addition to the ammonia, a nitro group. It was therefore quite natural that the two chemists should join forces, and in 1856 their celebrated memoir appeared. In this memoir thirty-five salts were described, of the four bases roseocobalt, purpureocobalt, luteocobalt, and xanthocobalt, with adequate analyses, and in eleven cases crystallographic measurements by J. D. Dana. The roseo- and purpureo-compounds were for the first time clearly discriminated, although they were supposed to be isomeric—a misconception which could hardly have been avoided at that time. There was also an elaborate theoretical discussion upon the constitution of the bases, but that also was premature. The fundamental theories of structure were yet to be developed. Blomstrand, Jörgensen, and Werner, in later years, utilized the data of Gibbs and Genth, and Werner especially made the ammonio-cobalt compounds the basis of his famous theory of the constitution of the metalamines. Gibbs and Genth laid the foundations on which later investigators have built an imposing structure.

Gibbs was an experimentalist rather than a theorist, and yet he neither underrated nor avoided theory. In 1867 he published a paper upon atomicities, or valences, as they are now called, in which he developed the idea, then vaguely held by others, of residual affinities. He argued in favor of the quadrivalency of oxygen, and showed that on that supposition a molecule of water must be bivalent, and any chain of water molecules would be bivalent also. He then considered ammonia in the same way, with the two bonds of quinquivalent nitrogen unsatisfied. Ammonia, therefore, was weakly bivalent, and so, too, would be a chain of ammonia molecules. This conception he applied to the interpretation of the ammonio-cobalt bases, and so, too, did Blomstrand two years later. If we consider theories of this kind not as finalities, but as attempts to express known relations in symbolic forms, we must admit that Gibbs' conception was useful, and served well for the time being. That it has given way to other views more in harmony with modern discoveries, is not at all to the discredit of its author. In the later papers by Gibbs, published in 1875 and 1876, he made good use of his hypotheses, and described many more ammonio-cobalt compounds. Among them were the salts of an entirely new base, croceocobalt, in which two nitro-groups were present. In all, five distinct series were studied, their chlorides being represented, in modern notation, by the subjoined formulæ:

Luteocobalt chloride..........	$Co(NH_3)_6Cl_3$.
Roseocobalt chloride..........	$Co(NH_3)_5.H_2O.Cl_3$.
Purpureocobalt chloride.......	$Co(NH_3)_5.Cl.Cl_2$.
Xanthocobalt chloride.........	$Co(NH_3)_5.NO_2.Cl_2$.
Croseocobalt chloride.........	$Co(NH_3)_4(NO_2)_2.Cl$.

Gibbs' formulæ were somewhat different from these, being doubled, and with the water of roseocobalt regarded not as constitutional, but as crystalline. The simpler, halved expressions were established by cryoscopic methods which did not exist when Gibbs conducted his investigations.

The researches upon the platinum metals, published by Gibbs in the years 1861 to 1864, relate mainly to analytical methods. Processes for the solution of iridosmine were carefully studied, and various new separations of the several metals from one another were devised. Incidentally, a number of new compounds were prepared, which, with a few exceptions, Gibbs never fully described. In 1871, however, he published a brief note on the remarkable complex nitrites formed by iridium,* and in 1881 he described a new base, osmyl-ditetramin, $OsO_2.4NH_3$, together with several of its salts. These researches were never pushed very far, and were discontinued for lack of proper facilities. They were, nevertheless, distinct additions to our knowledge of the platinum group.

I have already mentioned the work done by Gibbs and his students in the Laboratory of the Lawrence Scientific School. This covered a wide range, partly in developing and perfecting old analytical methods, partly in devising new ones. There were improvements in gas analysis, especially in the determination of nitrogen, and a great variety of analytical separations. I will not attempt to give a catalogue of these investigations, but will limit myself to a few of the more noteworthy. A new volumetric method for analyzing the salts of heavy metals was worked out, in which a metal such as copper or lead was precipitated as sulphide, the acid being afterwards determined by titration. The estimation of manganese as pyrophosphate was another of these contributions to analysis. But the most important of all was the electrolytic determination of copper, now

* Ber. Deutsch. chem. Ges., 4, 280. Not a separate paper, but part of his correspondence.

universally used, which was first published from Gibbs' laboratory. It is true that a German chemist, Luckow, claimed to have used the method much earlier, but so far as I can discover he failed to publish it. Gibbs, therefore, is entitled to full credit for a process which was the progenitor of many others. The entire field of electro-chemical analysis was thrown open by him, and it has been most profitably cultivated.* Gibbs also, during this period of his activity, invented several instrumental devices of great convenience. The ring burner, and the use of porous septa when precipitates are to be heated in gases, are due to him. Furthermore, in coöperation with E. R. Taylor, he devised a glass and sand filter which was the forerunner of the porous cones invented by Munroe when the latter was a student in Gibbs laboratory. That, in turn, preceded the well-known perforated crucibles of Gooch, who was one of Gibbs' assistants. The genealogy of these inventions is perfectly clear.

We come now to the remarkable series of researches upon the complex inorganic acids, which Gibbs began to publish in 1877, and continued well into the nineties. The ground had already been broken by others; silicotungstates, phosphotungstates, phosphomolybdates, etc., were fairly well known, but they were commonly regarded as exceptional compounds rather than as representatives of a very general class. In his first preliminary communication upon the subject Gibbs indicated the vastness of the field to be explored, and showed that the formation of complex acids was characteristic of tungsten and molybdenum to an extraordinary degree. The phenomena were general, not special; and no limit could be assigned to the possible number of acids which these elements might form.

In his systematic work, following his preliminary announcement, Gibbs first revised the sodium tungstates in order to determine their true composition. Then, after preparing a number of phosphotungstates and phosphomolybdates, he studied the corresponding compounds containing arsenic in place of phosphorus. He next obtained similar vanadium compounds, and also showed that the phosphoric oxide of the first known

*Notably by Smith in this country, and Classen in Germany.

acids was replaceable by phosphorous and hypophosphorous groups. Later still, he replaced the normal phosphates by pyro- and meta-phosphates, and also prepared complex salts containing arsenious, antimonious, and antimonic radicles. Stanno-phosphotungstates and molybdates, platinotungstates, and complex acids containing mixed groups were discovered, together with analogous compounds of selenium, tellurium, cerium, and uranium. One salt described, a phospho-vanadio-vanadico-tungstate of barium, had the formula

$$60\ WO_3.3P_2O_5.V_2O_5.VO_2.18BaO.150H_2O,$$

with a molecular weight of 20066. Compared with this substance the supposed complexity of most organic compounds becomes simplicity itself, and their interpretation seems relatively like child's play. In all, Gibbs described complex salts belonging to more than fifty distinct series, and did his work in a small private laboratory, with only a single assistant. With greater resources at his command, what might he not have accomplished?

In 1898, in his address as retiring president of the American Association for the Advancement of Science, Gibbs summed up his views as to the constitution of the complex acids. His presentation of the subject, however, can hardly be regarded as final. The problems involved are too complicated to be easily solved, and much future investigation is needed in order to determine the true character of these extraordinary substances. Gibbs was a pioneer, breaking pathways into a tangled wilderness; but the ways are now open, and he who wills may follow. Possibly some of the compounds so far obtained were double salts; others may have been isomorphous mixtures; and in some instances phenomena of solid solution perhaps obscured the truth. By physical methods, cryoscopic or ebullioscopic, the molecular weights of the salts must be determined; their ionization needs to be studied, and in such ways their true nature can be ascertained. These methods of research have been mainly developed since the work of Gibbs was done; he therefore cannot be criticised for not employing them. Since his time chemists have come to recognize many compounds as salts containing complex ions, such as, for example, the oxalates, tartrates, etc., of iron, aluminum, chromium, and antimony, with other bases of lower valency. Even many of the silicates are easiest to interpret as salts of alumino-silicic acids, although the physical proof of their nature is difficult to obtain. The constitution of the complex acids is one of the great outstanding problems of inorganic chemistry.

Although he was distinctively an inorganic chemist, Gibbs did not entirely neglect organic chemistry. In 1868 he discussed the constitution of uric acid and its derivatives, and in 1869 he described some products formed by the action of alkaline nitrites upon them. He also produced several memoirs upon optical subjects, such as one upon a normal map of the solar spectrum, and another upon the wave lengths of the elementary spectral lines. Again, he devoted some time to the study of interference phenomena, and discovered a constant, which he called the interferential constant, that was independent of temperature. One of Gibbs' latest papers, published when he was seventy-one years old, related to that extremely difficult subject, the separation of the rare earths—a subject in which he had always taken a deep interest. In this paper he developed a new method for determining the atomic weights of the rare-earth metals, which was based upon analyses of their oxalates. The oxalic acid was determined by titration with permanganate solutions, and the oxides by ignition of the salts. From the ratios between the oxalic acid and the oxides the molecular weights of the latter could be computed without reference to the amount of moisture in the initial substances. This method has since been employed by others, and especially by Brauner, in his work on the atomic weights of cerium and lanthanum. It is worth noting here that Gibbs had previously taken some part in atomic weight determinations. Those of Wing on cerium, and of Lee on cobalt and nickel, were made in Gibbs' laboratory and under his guidance. Furthermore, Gibbs was one of the earliest American chemists, if not the first, to accept the modern or Cannizzaro system of atomic weights, and to use it in his teaching. His mind was never closed to new ideas. It welcomed light from all sources.

Gibbs wrote no books and delivered no popular lectures. He was therefore little known to the public at large, but within scientific circles he received high honors. He was president of the National Academy of Sciences from 1895 to 1900, and he also presided over the American Association for the Advancement of Science in 1897. Honorary membership in the German, English, and American chemical societies, and in the Prussian Academy was conferred upon him, and he received honorary degrees from several universities. His life was that of a devoted scholar, caring most for research, and indifferent to popularity. Sensationalism and self-advertising were most obnoxious to him; indeed, in these respects, no man could have been more fastidious. The approval of his fellows he fully appreciated, but only when it was spontaneous and deserved. It must not be inferred from these remarks that Gibbs was deficient in public spirit, for that would be most untrue. During the Civil War, from 1861 to 1865, he was strongly patriotic, and did much to help the Union side. The Union League Club of New York, organized to bring together the more patriotic citizens of that city, was founded at a meeting in his house, and is today a strong social institution. Gibbs was also active in the Sanitary Commission, an organization modeled upon the work of Florence Nightingale in the Crimea, and the forerunner of the Red Cross Society of today.

Wolcott Gibbs was a man of striking personality, tall, erect, and dignified. As with most men of positive character, he had strong likes and dislikes, but the latter never assumed unworthy form. To his friends he was warmly devoted, and always ready to help them in their work with manifold suggestions. His breadth of mind is indicated by the range of his researches, and his liberality by the way in which he encouraged his students to develop his ideas. More than one important investigation was based upon hints received from him, and was carried out under his supervision, to appear later under another name. Gibbs never absorbed the credit due even in part to others, nor failed to recognize the merits of his assistants in the fullest way. Had he been more selfish, his list of publications would have lengthened, but his sense of justice was most keen, and therefore he held the esteem and confidence of his co-workers. No man, not even among his opponents, for such there were, could ever accuse him of unfairness. He deserved all honor, and his name will live long in the history of that science to which his life was given.

BIBLIOGRAPHY*

Description of a new form of magneto-electric machine, and an account of a carbon battery of considerable energy. American Journ. Sci., 1st ser., Vol. XXXIX, 1840, pp. 132–134.

Remarks on the theory of compound salt radicals. American Journ. Sci., 1st ser., Vol. XLVI, 1844, pp. 52–56.

Dissertation on a natural system of chemical classification. American Journ. Sci., 1st ser., Vol. XLIX, 1845, pp. 384–386. (A review of a work by Gibbs.)

Chemisch-mineralogische Untersuchungen. Poggend. Annal, Vol. LXXI, 1847, p. 559.

On the influence of temperature in the absorption of light. Proc. American Assoc. Adv. Sci. for 1850, Vol. IV, 1851, pp. 296–297.

Analysis of the sirocco dust of Genoa. American Journ. Sci., 2d ser., Vol. XI, 1851, p. 374. (Incidental to a paper by C. G. Ehrenberg.)

Note on Williamson's "Theory of the formation of ether." American Journ. Sci., 2d ser., Vol. XI, 1851, p. 422.

Note on Cahour's investigation of anisol. American Journ. Sci., 2d ser., Vol. XI, 1851, p. 423.

Contributions to analytical chemistry. American Journ. Sci., 2d ser., Vol. XIV, 1852, pp. 204–209.

Note on the kakodyl of valerianic acid. American Journ. Sci., 2d ser., Vol. XV, 1853, p. 118.

Note on a new electro-chronometric method. Proc. American Assoc. Adv. Sci. for 1854, Vol. VIII, 1855, pp. 103–106.

Report on the recent progress of organic chemistry. Proc. American Assoc. Adv. Sci. for 1855, Vol. IX, 1856, pp. 37–61.

On the theory of the polyacid bases. Proc. American Assoc. Adv. Sci. for 1858, Vol. XII, 1858, pp. 190–197.

Preliminary notice of new bases containing metals associated with ammonia. Proc. American Assoc. Adv. Sci. for 1858, Vol. XII, 1859, pp. 197–200.

On the rational constitution of certain organic compounds. American Journ. Sci., 2d ser., Vol. XXV, 1858, pp. 18–38.

Researches on the platinum metals. American Journ. Sci., 2d ser., Vol. XXXI, 1861, pp. 63–71.

Remarks on the atomic weights of the elements. American Journ. Sci., 2d ser., Vol. XXXI, 1861, pp. 246–251.

Researches on the platinum metals. American Journ. Sci., 2d ser., Vol. XXXIV, 1862, pp. 341–356.

* In the Royal Society's Catalogue of Scientific Papers an article is ascribed to Gibbs which was published in 1825. It should be credited to his father, Col. George Gibbs.

Researches on the platinum metals. American Journ. Sci., 2d ser., Vol. XXXVII, 1864, pp. 57–61.

Note on niobic acid. American Journ. Sci., 2d ser., Vol. XXXVII, 1864, p. 118.

Note on Rose's "On a new series of metallic oxyds." American Journ. Sci., 2d ser., Vol. XXXVII, 1864, pp. 119–120.

On the relation of hyposulphate of soda to certain metallic oxyds. American Journ. Sci., 2d ser., Vol. XXXVII, 1864, pp. 346–350.*

On the determination of nitrogen by weight. Idem, pp. 350–352.*

On the separation of cerium from didymium and lanthanum. Idem, pp. 352–354.*

On the separation and estimation of cerium. Idem, p. 354.*

On the quantitative separation of cerium from yttrium, aluminum, glucinum, manganese, iron, and uranium. Idem, pp. 354–355.*

On the employment of fluohydrate of fluorid of potassium in analysis. Idem, pp. 355–358.*

On the separation of chromium from aluminum, iron, manganese, cobalt, nickel, zinc, and magnesium. American Journ. Sci., 2d ser., Vol. XXXIX, 1865, pp. 58–60.†

On the employment of acetate of sodium for the separation of iron and aluminum from other bases. Idem, pp. 60–61.†

On the separation of manganese from cobalt, nickel, and zinc. Idem, pp. 61–63.†

On the separation of cobalt from nickel. Idem, pp. 63–64.†

On the separation of uranium from zinc, cobalt, and nickel. Idem, p. 64.†

On the electrolytic precipitation of copper and nickel as a method of analysis. Idem, pp. 64–65.†

Note on the wave length of Fraunhofer's lines. American Journ. Sci., 2d ser., Vol. XXXIX, 1865, pp. 217–218.

On the construction of a normal map of the solar spectrum. American Journ. Sci., 2d ser., Vol. XLIII, 1866, pp. 1–10.

On a new general method of volumetric analysis. American Journ. Sci., 2d ser., Vol. XLIV, 1867, pp. 207–210.‡

On the precipitation of copper by hypophosphorous acid. Idem, pp. 210–213.‡

On the precipitation of copper and nickel by alkaline carbonates. Idem, pp. 213–215.‡

On the employment of sand and glass filters in quantitative analysis. Idem, pp. 215–216.‡

On the estimation of manganese as pyrophosphate. Idem, pp. 216–217.‡

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* Under the general title (p. 346): "Contributions to chemistry from the laboratory of the Lawrence Scientific School, No. 1."

† Under the general title (p. 58): "Contributions to chemistry from the laboratory of the Lawrence Scientific School, No. 2."

‡ Under the general title (p. 207): "Contributions to chemistry from the laboratory of the Lawrence Scientific School, No. 3."

On certain points in the theory of atomicities. American Journ. Sci., 2d ser., Vol. XLIV, 1867, pp. 409–416.

On the measurement of wave-lengths by the method of comparison. American Journ. Sci., 2d ser., Vol. XLV, 1868, pp. 298–301.

On the molecular structure of uric acid and its derivatives. American Journ. Sci., 2d ser., Vol. XLVI, 1868, pp. 289–298.

On the wave-lengths of the spectral lines of the elements. American Journ. Sci., 2d ser., Vol. XLVII, 1869, pp. 194–218.

On the action of the alkaline nitrates upon uric acid and its derivatives. American Journ. Sci., 2d ser., Vol. XLVIII, 1869, pp. 215–226.

On a simple method of avoiding observations of temperature and pressure in gas analysis. American Journ. Sci., 2d ser., Vol. XLIX, 1870, pp. 376–377.*

On the application of Sprengel's mercurial pump in analysis. Idem, pp. 378–381.*

On the measurement of wave-lengths by means of indices of refraction. American Journ. Sci., 2d ser., Vol. L, 1870, pp. 45–50.†

On liquids of high dispersive power. Idem, pp. 50–52.†

On an advantageous form of apparatus for the study of the absorption of light in colored liquids. Idem, pp. 52–53.†

On tests for the perfection and parallelism of plane surfaces of glass. Idem, pp. 53–54.†

On the quantitative estimation of chromium and the separation of chromium from uranium. American Journ. Sci., 3d ser., Vol. V, 1873, pp. 110–113.‡

On the estimation of magnesium as pyrophosphate. Idem, pp. 114–115.‡

On the estimation of cobalt. Idem, p. 115.‡

On some forms of laboratory apparatus. Idem, pp. 115–117.‡

Researches on the hexatomic compounds of cobalt. American Journ. Sci., 3d ser., Vol. VI, 1873, pp. 116–126.

Researches on the hexatomic compounds of cobalt. Proc. American Acad. Arts and Sci., Vol. X (new series, Vol. II), 1875, pp. 1–38.

On a new optical constant. Proc. American Acad. Arts and Sci., Vol. X (new series, Vol. II), 1875, pp. 401–416.§

On a method of measuring refractive indices without the use of divided instruments. Idem, pp. 417–420.§

Researches on the hexatomic compounds of cobalt. Proc. American Acad. Arts and Sci., Vol. XI (new series, Vol. III), 1876, pp. 1–51.

On complex inorganic acids. American Journ. Sci., 3d ser., Vol. XIV, 1877, pp. 61–64.

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* Under the general title (p. 376): "Contributions to chemistry from the laboratory of the Lawrence Scientific School, No. 11."

† Under the general title (p. 45): "Miscellaneous optical notices."

‡ Under the general title (p. 110): "Analytical notices."

§ Under the general title (p. 401): "Optical notices."

On the complex inorganic acids. American Chem. Journ., Vol. I, 1880, pp. 1–4.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XV (new series, Vol. VII), 1880, pp. 1–21.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XVI (new series, Vol. VIII), 1881, pp. 109–139.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XVII (new series, Vol. IX), 1882, pp. 62–90.
On osmyl-ditetramin. American Chem. Journ., Vol. III, 1882, pp. 233–241.
On complex inorganic acids. American Chem. Journ., Vol. IV, 1883, pp. 377–380.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XVIII (new series, Vol. X), 1883, pp. 232–274.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XXI (new series, Vol. XIII), 1885, pp. 50–128.
Note on the electrolytic determination of metals as amalgams. American Chem. Journ., Vol. XIII, 1891, pp. 570–571.
Notes on the oxides contained in cerite, samarskite, gadolinite, and fergusonite. American Chem. Journ., Vol. XV, 1893, pp. 546–566.
Researches on the complex inorganic acids. Proc. American Acad. Arts and Sci., Vol. XXX (new series, Vol. XXII), 1894, pp. 251–282.
Address as retiring president of the American Association for the Advancement of Science. Proc. American Assoc. Adv. Sci. for 1898, Vol. XLVII, 1898, pp. 1–16.

WITH F. A. GENTH.

Researches on the ammonia-cobalt bases. Smithsonian Contributions to Knowledge, IX, 1857.
Preliminary notice of a new base containing osmium and the elements of ammonia. American Journ. Sci., 2d ser., Vol. XXV, 1858, p. 248.

WITH H. A. HARE.

A systematic study of the action of definitely related chemical compounds upon animals. American Chem. Journ., Vol. XI, 1889, pp. 435–448; and Vol. XII, 1890, pp. 145–152; and pp. 365–379.

WITH E. T. REICHERT.

A systematic study of the action of definitely related chemical compounds upon animals. American Chem. Journ., Vol. XIII, 1891, pp. 289–307 and pp. 361–370; and Vol. XVI, 1894, pp. 443–449.