SCIENCE

FRIDAY, DECEMBER 17, 1915

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

RECENT RESEARCHES IN THE WOLCOTT GIBBS MEMORIAL LABORATORY OF HARVARD UNIVERSITY[1]

THE Wolcott Gibbs Memorial Laboratory of Harvard University is one of the most significant monuments ever built in memory of a chemical investigator. So far as I know, only the Davy-Faraday Laboratory in London, the van't Hoff Laboratory in Utrecht, and the Hofmann Haus in Berlin equal it in importance. Because Professor Wolcott Gibbs was one of the founders and presidents of the National Academy of Sciences, an account of the memorial building and of its first fruits is especially appropriate here to-day.

The new laboratory was initiated by the late Dr. Morris Loeb, the devoted and able pupil of Gibbs. He and his brother, James Loeb, subscribed $50,000, provided that other friends of Harvard University should raise $50,000 more. With admirable feeling, Dr. Loeb especially desired that the building should be named in honor of his former teacher and friend. In March, 1910, Dr. Alexander Forbes and other generous donors having greatly helped, the fund was completed; and in January, 1913, the building was opened for work, so that it has now been almost three years in full activity.

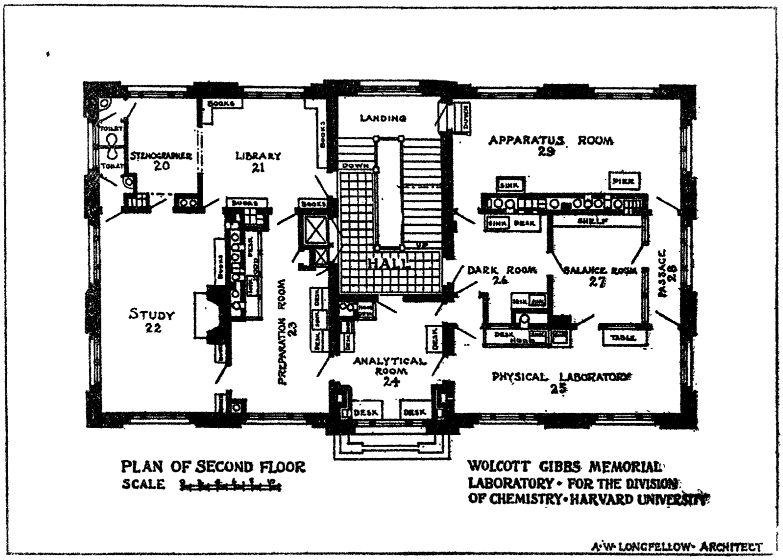
It is a great pleasure to express here the very lively gratitude, both on behalf of the university and on my own account, which I feel for the liberal interest of all these benefactors in the construction of this building.

Being the first of a large group of chem-

---

[1] Address delivered at the meeting of the National Academy of Sciences in New York, November 16, 1915.

ical laboratories planned for the department of chemistry at Harvard University, it was designed with especial care. Red "Harvard" brick with Indiana limestone trimmings, and Deer Isle granite foundations, constitute its external dress; the architectural details, due to A. W. Longfellow, are simple, effective and in good taste. It covers an area of 71 by 41 feet, and is 48 feet high. The construction is extremely solid and substantial, so that it is unusually free from vibration. Within, it is built of brick and reenforced concrete; and although there is some woodwork in doors and furniture, the building is practically incombustible. Hollow bricks and doubly glazed windows with tight weather-strips protect it from heat and cold, and the temperature of almost every room is automatically regulated. The ventilating plant provides filtered air, hence the building is extraordinarily free from dust throughout. Because the laboratory was designed and is used wholly for research, it contains no lecture room, but is divided into many rather small rooms of different sizes, intended for one, two or more investigators, according to the character of the work. There are many balance rooms, dark rooms and other necessities for accurate chemical experimentation, as well as rooms designed for both chemical and physical laboratories, because the work to be done lies on the border-line between chemistry and physics. Pipes are laid for hot and cold water, distilled water, steam, compressed air, oxygen and vacuum, as well as for gas; and electricity of many voltages is available at suitable plugs throughout. An automatic electric lift is used for transferring the apparatus, and telephones connect all the important rooms. The building has six floors available for work: three regular stories, a very light and convenient basement, a sub-basement for especially constant temperature work entirely underground, and a practicable roof. Perhaps the most important feature in its design is the arrangement of the balance rooms, dark rooms and laboratories in suites, so planned as to give the greatest possible usefulness to each, in the manner illustrated by the right-hand side of the



plan of the second floor. The arrangement is similar, not only on both ends of the third floor, but on the western end of the ground floor. Rooms are provided in the basement for the storage and handling of apparatus, a workshop, storage batteries, switchboards and other purposes. But a complete description of this laboratory and of its virtues would take far too much time for the present occasion.[2] It is enough to say that the three years' work in it have shown it to be ideally adapted to the sort of investigation for which it had been planned.

In the front hall stands a bronze bust of Wolcott Gibbs with a marble tablet bearing the inscription:

WOLCOTT GIBBS
FEB 21 1822–DEC 9 1908
RUMFORD PROFESSOR
HARVARD UNIVERSITY
1863–1887 EMERITUS 1887–1908
PATHFINDER IN AMERICAN CHEMISTRY

With the building came a fund bearing an income sufficient for heating and janitor service, but not enough to purchase any suitable amount of special apparatus. Therefore, the subsidies which the director has received from the Carnegie Institution of Washington have been of very great use in providing part of the equipment of scientific apparatus and additional expert assistance. Indeed, without such help but little could have been done. I take great pleasure, therefore, in expressing my indebtedness to this institution, and feel that it shares with Harvard University and the generous founders in any credit which may be attached to the output of the laboratory. Also to the able assistants and advanced students who have helped me with so much patience and enthusiasm, I am deeply grateful. Twenty-four in number, they have been, of course, chiefly Americans (by no means all Harvard men), but the list includes four Canadians, an Icelander, a Dane, a Japanese, and a German. Moreover, the laboratory now harbors two guests, one conducting a research on the chemical activity of radium emanations and the other on the acidity of sea water. These two investigators are collaborating with colleagues who have no such suitable place elsewhere to offer for the investigations. Concerning these researches, however, it is not my province to speak.

What now has been the first fruit of this building? For the architectural shell is only a means, not an end in itself; and except as a memorial its existence is justified only by the work accomplished within it. During the past three years 24 papers have been published from this laboratory, and a number of other investigations have been almost finished and are being prepared for publication. Their character varies widely, ranging from almost pure chemistry to almost pure physics, but, in spite of the diversity, there is, for the most part, a common aim underlying them all. This aim is a careful study of the fundamental properties of the chemical elements—those substances which constitute the basis of our visible and tangible universe. Among these fundamental properties may be mentioned their atomic weights, their densities and compressibilities, their electromotive behavior and heat of combination with other elements and, finally, the physical and chemical properties of their simple compounds. Let us consider briefly the several investigations already published and now in progress.

Turning, first, to the study of atomic weights, three investigations on this subject have already yielded publications. The first of these was a research upon the atomic weight of carbon, in which sodium carbonate was prepared in an unusual degree of

---

[2] A fuller description of the laboratory was published in the *Harvard Alumni Bulletin* for March 26, 1913.

purity and converted into sodium bromide, the amount of silver necessary to precipitate the combined bromine being determined. In this way the relation between the atomic weights of bromine and carbon was determined, and the agreement of the values thus found with the parallel work of others gives very satisfactory evidence of the trustworthiness of all the other atomic weights which have been determined at Harvard in relation to bromine. Next came the study of the atomic weight of sulphur, which was studied in somewhat similar fashion, pure sodium carbonate being converted into pure sodium sulphate, and thus the relation between carbon and sulphur found through those salts. The value of sulphur obtained in this way was somewhat less than that ordinarily accepted, but not more than might reasonably be ascribed to the possible errors of previous work. On the whole, these two investigations, in which the purest sodium carbonate formed the starting point, add distinctly to one's confidence in the present accepted table of atomic weights. Both of these investigations were so extremely delicate and so very dependent upon pure, dust-free air that they could hardly have been executed at all in a less perfect building.

Next, during 1913–14 the atomic weight of lead from radioactive sources was studied; and we found that this sort of lead has an atomic weight distinctly lower than ordinary lead, although no known impurity could be found in it, and although its ultra-violet spectrum is identical with that of ordinary lead. This work was soon supported by independent and almost simultaneous but less complete and searching investigations published in Austria and France; and later has been reenforced by continued research in both continents. The outcome has unusual interest and significance, because it seems to indicate that there may be different kinds of lead having many properties precisely similar, but differing as to their atomic weights. The research is being continued at the Wolcott Gibbs Memorial Laboratory, large amounts of radioactive lead having been obtained from Australia, Colorado and Norway through the kindness of scientific friends.

Whatever may be the final outcome, one can not help thinking that researches of this kind deal with mysteries which are among the most fundamental of all those presented to the physical chemist, for the nature of the chemical elements underlies all the mechanism upon which life depends.

The study of compressibility was continued in two directions—on the one hand, the behavior under pressure of similar organic substances, and on the other hand, the compressibility of the elements, being carefully studied with increasing accuracy and effectiveness. This seems rather a strange subject to pursue in a chemical laboratory; but its interest is truly chemical, because of its relation to the recent theory of atomic compressibility, which gives a new interpretation of the mechanism of chemical action. There is not time to expound this theory at length here, but those who desire acquaintance with it will find a fairly complete résumé in the number of the *Journal of the American Chemical Society* for last December.[3] Suffice it to say that many facts may be interpreted to mean that the atoms are not hard, incompressible particles, but rather elastic, compressible, deformable entities, capable of yielding somewhat to every source of pressure which may be applied upon them. Moreover, evidence is available showing that both chemical affinity and cohesion exert pressure in their action, and hence affect the space

---

[3] *Jour. Am. Chem. Soc.*, 36, 2417–2439 (1914). Many references to other papers on this topic are given in the accompanying bibliography.

occupied by the atoms. In the interpretation of all the facts, knowledge of the compressibility of elements and compounds is essential; and as the available data are scarce, work in this direction was prosecuted with vigor. It is enough to say that the compressibility of over a score of organic substances and of nine elements (namely, tungsten, molybdenum, tantalum, boron, copper, iron, lead, thallium and mercury) have been determined during the last three years, either for the first time or at least with more accuracy than ever before. The apparatus for this purpose has been studied with a view to the detection of all the insidious minor errors which may affect work of this kind, and has been distinctly improved in several ways. Some of the theoretical outcomes of this work, which shows that the compressibilities of the elements are periodic, like their atomic volumes, have been briefly expounded in the July number of the new *Proceedings* of this academy. Here it is shown that the compressibility of the elements seems to depend in a large degree upon the atomic volumes and melting points of the several elements.

A revision of thermochemical data, which has been in progress for a number of years, has been especially advanced during the last three years in the Wolcott Gibbs Memorial Laboratory. The method of protecting a calorimeter from accidental heating or cooling, by always keeping the jacket around it at just the same temperature as the calorimeter itself, has been found efficient and convenient. Automatic contrivances called "synthermal regulators" for maintaining this identity of the two temperatures have been devised, and in various details the calorimetric procedure has been perfected. This method, by the way, which as applied to calorimeters of changing temperatures took its origin at Harvard, is spreading rapidly over the world, and has now adherents not only in various parts of America, but even so far away as Moscow.

The heat given out by the combustion of many organic substances has been studied, especial emphasis having been laid upon the danger of incompletely burning the more volatile compounds, which evaporate too quickly to be burned all at once; and precautions have been perfected for preventing this error. In addition, methods for determining the heat evolved during the solution of metals in acids, the neutralization of acids and alkalies, as well as for finding the specific heats of solutions—data which form the basis of all the thermochemistry of metallic salts—have been improved and amplified. In connection with these researches upon the heat evolved in chemical action, a study of methods of calibrating thermometers, of determining fixed points upon them by the transition temperatures of pure salts, and of subdividing the intervals between the fixed points in various ways so as to correspond exactly to the true temperature scale, has been carefully conducted. Also, considerable time was spent upon the further investigation of floating equilibrium—the point at which a sunken sealed float of fixed volume neither rises nor sinks in a liquid. The effect of concentration of various solutions on the temperature of this equilibrium was studied, as well as the slight volume changes suffered by the float with time, temperature and pressure. It has been shown that with due care this phenomenon may be used for either analyzing solutions or standardizing thermometers.

An interesting physico-chemical problem connected with the study of transition temperatures is the effect upon the crystalline "melting points" of impurities which crystallize out with deposited salts. In particular, the effect of sodium sulphate on the "melting point" of hydrated sodium chromate, and the effect of strontium bromide on strontium chloride, were both carefully studied.

Another investigation allied both to that just mentioned and to the work on compressibility, is the effect of pressure upon the solubility of salts. Theoretically as well as experimentally this is not a new subject, but there is still great need for the procuring of accurate data. A small but practicable apparatus was devised, making possible the determination of this effect as far as 600 atmospheres pressure, and preliminary results have already been obtained upon a number of typical salts. These investigations also are still being continued.

Turning now to the electrochemical side of our activities: during the past three years we have studied anew the precautions necessary in order to determine exactly the weight of silver deposited from its solutions by the galvanic current—a problem which has a distinctly practical bearing, in that the weight of deposited silver is one of the most satisfactory measures of the quantity of electricity flowing through the solution. There can be little doubt that this weight is in precise accord with the demands of Faraday's law of electrolysis, that is to say, is directly dependent upon the atomic weight of silver; but disturbing circumstances enter into the actual determination and one of the most important outcomes of this work was to show once more that the silver under some circumstances may carry down with it appreciable amounts of the solution from which it was deposited, thus increasing its apparent weight and leading to a somewhat erroneous estimate of the relation between quantity of electricity and quantity of substance. This investigation is being continued not only at this laboratory, but also at the Bureau of Standards and at Princeton University.

The electromotive forces manifested by metals and amalgams in appropriate solutions have a significant bearing on the energetic side of chemistry, being concerned not only with the important effect of concentration on chemical change, but also with chemical affinity itself. On this account these electromotive forces have not been neglected in the Gibbs Laboratory, the behavior of concentrated thallium amalgams and alloys of sodium and lead having received attention. The interesting details of these experimental researches are too technical and too elaborate for a brief statement of this kind.

Yet another electrical phenomenon investigated was the dielectric behavior of non-conducting organic substances. The dielectric constants of nearly a score of very pure organic substances were determined by means of a modification of a standard method, which was improved and made much more sensitive and accurate.

In keeping with the plan to study and compare all the important physical properties of typical chemical substances, the densities, melting points and boiling points of many substances mentioned above, which had been purified with very great care, were determined, taking pains about accuracy in the thermometric measurements not usual in chemical laboratories. It is especially interesting, in view of the difficulty of complete purification, to have all these various properties determined on the same uniformly pure samples of material, so that the true correlation between the different properties can be discovered; for, obviously, if one sample containing one set of impurities is used for determining density, and another sample with another set of impurities is used for determining the boiling point, any relation which may exist between these two properties may be quite obscured by the different impurities. This is what generally happens when different people study the properties of varying samples.

One of the most recently undertaken of all these investigations is the study of surface tension of these same organic liquids. Surface tension, as you well know, is that tendency (caused doubtless by the cohesion of the molecules of substance) which forces any liquid surface to contract as much as possible, thus making drops and bubbles spherical, and drawing liquids up in capillary tubes. Surface tension is of peculiar interest in relation to the theory of compressible atoms, because it gives another clue to the cohesive forces holding matter together in the liquid and solid condition; but the published data even for such a common substance as water vary widely, often as much as 10 per cent. Hence the more careful study of this important property formed a legitimate part of the scheme of investigation for which the Wolcott Gibbs Memorial Laboratory was planned. In the first year of this research, which is being continued at the present time, we were able to find most of the important causes of the serious divergences in earlier work. Many of the experimenters had immersed their capillary tubes (in which the effect was to be measured) in other tubes much too narrow for the purpose, not realizing that even a tube one inch in diameter causes an appreciable "capillary" rise of the liquid contained within it. Again, they failed to allow for optical imperfections in the glass of the tubes containing the liquid, their methods of measurement were sometimes inadequate, and the mathematical formulæ used for calculating the results were often faulty. Therefore, in our preliminary work, which was reviewed briefly in the July number of the *Proceedings* of this academy, it is hoped that a distinct advance has been made.

If high quality had not been sought, of course the number of investigations could have been much greater. Some one has wisely said that the output of physico-chemical work is inversely proportional to the square of the grade of accuracy desired. In the brief space of these few minutes it has been impossible to give much more than a mere list. Those of you who are specially interested will find many of the researches already published in full; brief accounts of others are in the Year Books of the Carnegie Institution of Washington, and before long it is hoped that the rest also may be printed.

An investigator for whom much has been done feels gravely the responsibility which rests upon him of doing much in return; and although in this case he feels the necessary human inadequacy and incompleteness of the work just described, nevertheless he hopes that at least a beginning of accomplishment has been made, and that in the future the Wolcott Gibbs Memorial Laboratory, through many years, will yield ever increasingly useful additions to the sum of human knowledge.

Theodore W. Richards
Harvard University

THE LIFE OF RADIUM

The life of radium, or the length of time required for a given quantity of radium to be transformed and converted into other elements, is a physical magnitude of considerable importance and interest. Its chief significance lies perhaps within the special field of radioactivity where radium occupies a unique position in being the only highly radioactive radio-element which possesses physical and chemical properties, and occurs in a sufficiently high state of