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EDGAR FAHS SMITH, CHEMIST[1]

IN turning the pages of that great final ledger wherein are recorded our life's endeavors and accomplishments, I find a noteworthy account which reads thus:

AMERICAN CHEMISTRY

Debtor to Edgar Fahs Smith, of Philadelphia, Pennsylvania. For services rendered from September, 1876, to May 3, 1928, 52 years, as follows:

Item 1.—As educator, who with rare charm and power, portrayed to tens of thousands of his fellow Americans, both students and others, the multifarious and marvelous ways in which chemistry contributes to the advancement of civilization and to the prosperity and happiness of the individual, how its work is carried on, the splendid opportunities it offers for service to mankind and what it may reasonably expect to accomplish in the very near future; with the result that the public were given a better appreciation and a clearer understanding of its importance to their well-being, and that the many young people thereby induced to make chemistry their life's business received a training and an inspiration which made them more useful and more patriotic citizens of higher and nobler ideals.

Item 2.—As guide, counselor and loyal friend to all who were so fortunate as to know him and especially as older brother to all younger chemists. No one who approached him ever failed to receive a cordial welcome, a patient and sympathetic hearing of his problem, whether scientific or personal, and sound advice as to the proper line of action. In the laboratories he labored not merely shoulder to shoulder but heart to heart with his staff and students. Their sorrows and unhappiness brought grief to him. In their triumphs and happiness he rejoiced. Into their characters he built his own, and that memory will remain to these generations of students as a refining and ennobling influence which will continue until they too will have completed "life's great adventure." The world's tributes of honors and decorations are but as dross compared to these priceless riches of human lives. The alumni will read with pride the long list of his honors, but these honors will not cause the same tug at the heart-strings as the recollection of the touch of his hand, the sound of his friendly voice or the welcoming smile upon his well-beloved face.

Item 3.—As an example to all of the beauty and dignity of a life of simplicity, self-forgetfulness and devotion to all that is noblest and best, and the fact that a chemist is also an American citizen and as such owes to his country the discharge of those civic and patriotic duties for which his talents and training especially fit him

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[1] Address delivered at the meeting in memory of Edgar Fahs Smith, in Philadelphia, on December 4, 1928.

or which are properly expected of all good citizens. There is a great need for chemists in public life, but few are found willing to make the sacrifices which such service entails.

As member of the U. S. Assay Commissions of 1895 and 1901–5; as member of the electoral college for Pennsylvania in 1917, and as president of the same in 1925; as member of the Commission for the Revision of the Constitution of Pennsylvania in 1919; of the Committee for Public Safety, in 1919; of the College and University Council of the State of Pennsylvania from 1911 to 1920; of the State Council of Education from 1920 to 1922, and as member of the Board of Technical Advisers for the United States, and chairman of the International Committee on Poison Gases and High Explosives at the Disarmament Conference of 1921, he gave ungrudgingly and unstintedly of his time, strength and ability, to the solution of problems of importance to his state and his country, both of which are the poorer for his passing.

Item 4.—As author of books on theoretical and applied chemistry, some of which have gone through many editions and have been translated into French, German, Italian, Russian and Chinese. These books are "Electro-analysis," "Chemical Experiments for Students in General Chemistry" (with H. F. Keller), "Chemical Analysis of Urine," "Elements of Chemistry in Lecture Form," "Elements of Electrochemistry," "Theories of Chemistry," "Chemical Experiments, Shorter Course" and "Atomic Weights."

Of these, the books on the elements of electrochemistry and on electroanalysis were particularly valuable in directing attention and stimulating research in a field which prior to their appearance had been largely neglected.

Item 5.—As translator of books in other languages, thus making them available to English-speaking chemists. Such are Classen's "Quantitative Analysis," von Richter's "Inorganic Chemistry" and "Organic Chemistry," Oettel's "Introduction to Electrochemistry" and "Practical Exercises in Electrochemistry."

Item 6.—As biographer of American chemists and historian of American chemistry, a field in which he was not merely the recognized leader but was actually in a class by himself.

Item 7.—As a conspicuous illustration of the value to a chemist of an education also in literature and the liberal arts, so as to enable him to express in clear, convincing and attractive style those ideas or opinions which he is seeking to convey to his reader.

Item 8.—As member of numerous scientific organizations, as may be gathered from the following record: honorary member of the American Chemical Society and its president in 1895, 1920 and 1921; president of the American Philosophical Society from 1902 to 1908 and of the History of Science Society in 1928; honorary member of the American Electrochemical Society, of the Institute of Chemistry, of the Chemists' Club of New York, of the Engineers' Club of Philadelphia, of the Philadelphia College of Pharmacy and Science, of the Société do chimie industrielle of France, and of the Chemical, Mining and Metallurgical Society of South Africa; member of the National Academy of Sciences, of the Society of Chemical Industry and of the honor fraternities of Phi Beta Kappa and Sigma Xi; adviser in chemistry for the Carnegie Institution, 1902, and one of its research associates in 1915 and 1918–24; trustee of the Carnegie Foundation, 1914–20; member of the jury of awards at the Chicago Exposition, 1893, and president of the Wistar Institute from 1911 to 1922.

Item 9.—As original investigator in the fields of organic, inorganic, analytical and electrochemistry, as evidenced by over 160 scientific papers and the supervision of ninety-two doctor of philosophy dissertations.

Received in part payment of the above account:

The approbation, esteem and affection of all who knew him, as well as the highest honors from his fellow chemists, from his alma mater, from other educational and scientific organizations and from cities, states and nations.

Balance still due:

A permanent place in the Valhalla of Chemistry, the cherishing of his memory by all and the carrying forward of that flaming torch of devotion to the service of mankind which he himself bore so nobly and which he passed to us as his own strength ebbed away.

To convince ourselves that this bill is correct in all its particulars and specifications, let us examine somewhat more closely a few of its items.

Dr. Smith's chemical career may be said to fall roughly into the following periods, arranging them in chronological sequence and according to the fields of major activity at the time: I. Organic chemistry; II. inorganic, analytical and electrochemistry; III. historical chemistry.

I. ORGANIC CHEMISTRY

At the University of Göttingen, Edgar F. Smith pursued his studies in chemistry under the world-famous Friedrich Wöhler, and received the degrees of A.M. and Ph.D. from that institution in 1876. As a signal honor to Dr. Smith, these degrees were renewed by this university in 1926 for his "fifty years of science as teacher and investigator."

Upon his return to the United States, in the fall of 1876, he was appointed assistant in analytical chemistry to Professor F. A. Genth, in the Towne Scientific School of the University of Pennsylvania, leaving in 1881 to take the Asa Packer professorship of chemistry in Muhlenberg College, Allentown, Pennsylvania, where he remained for two years and then moved to Wittenberg College, Springfield, Ohio, as professor of chemistry, resigning his position in 1888 to accept the chair of analytical chemistry at the University of Pennsylvania made vacant by the resignation of Professor Genth. In 1892, following the retirement of Professor Samuel P. Sadtler, the man who really inspired him to devote his life to science, Dr. Smith was designated head of the department of chemistry, to which was added the title of vice provost when Dr. George S. Fullerton withdrew in 1898. The title of his chair was changed in 1907 to the Blanchard professorship of chemistry. His election as the thirteenth provost of the university occurred in 1911, following the resignation of Dr. Charles C. Harrison, and he carried the combined burdens of provost and professor of chemistry until his retirement in 1920 as an emeritus professor of chemistry.

At the University of Göttingen his research work for the doctorate had consisted in a study of "The Trisubstituted Benzole Compounds and the Action of Chlorine upon Benzyl Trichloride," in the course of which he investigated the effect of exhaustive chlorination of benzotrichloride, assisted by intermittent exposure to direct sunlight, and isolated a new chloride of carbon to which he assigned the formula $C_{21}Cl_{26}$ (m.p. 152°–153°), which was reduced by zinc and sulphuric acid to another new chloride, $C_{21}HCl_{25}$ (m.p. 102°), or by sodium amalgam to various unidentified products.[2]

Heated with aniline at 180°, it yielded a new crystalline and very easily soluble base, the constitution of which was not determined.[3]

After standing for twelve years, the melting-point of this $C_{21}Cl_{26}$ compound fell to 101°, although its percentage of carbon and hydrogen remained approximately the same.[4]

Salicylic acid was one of the organic compounds under investigation in the Göttingen laboratory during Dr. Smith's student days there, so that it is not surprising that we find him directing his own attention next to this interesting acid and its isomers, and in 1877[5] he published a paper "On a Dichlorsalicylic Acid and on Monochlorsalicylic Acid," in which he observed the formation of a dichloro (m.p. 212°–214°) and a monochloro (m.p. 172°) salicylic acid when chlorine was passed into an acetic acid solution of salicylic acid. Salts and other derivatives were prepared of both of these chloro acids.[6]

This work was an attempt to duplicate the results obtained by Rogers[7] who, by similar treatment of salicylic acid secured a dichloro acid of m.p. 224°.

Smith's acids were proved subsequently, by other investigators, to be the 3, 5-dichloro and 5-monochloro derivatives.

In association with Hoskinson[8] he showed that this same 5-chlorosalicylic acid (m.p. 172°), when treated with bromine in alcoholic solution, gave a bromochlorosalicylic acid (m.p. 229°), from which various salts and esters were prepared. He found, further, that the corresponding bromosalicylic acid, when iodinated in alcoholic solution by the method of Weselsky, yielded an iodobromosalicylic acid (m.p. 208°–209°), from which he also prepared certain salts and the methyl ester.

With Knerr[9] he proved that 5-chlorosalicylic acid could be converted into the iodochlorosalicylic acid by the action of iodine in alcoholic solution, in the presence of oxide of mercury, but that, in the absence of the latter, the product was the iodochlorobenzoic acid. Many salts of the iodochlorosalicylic acid were described.

As early as 1880[10] he effected a synthesis of salicylic from benzoic acid by heating copper benzoate and water together in a sealed tube for three hours at 180°, or benzoic acid, water and an ammoniacal solution of cupric oxide at 220°, although the yields in both cases were very low.

The delicacy of the salicylic acid reaction for ferric iron was tested by him[11] by adding an alcoholic solution of the acid to an aqueous one of ferric chloride, and it was found that 1/32,000th of a mg of iron could be detected in this way. With monochloro (m.p. 172°), or dibromosalicylic acid (m.p. 218°), the test was less delicate.

Smith and Knerr[12] discovered that when nitrous anhydride was passed into an ethereal solution of oil of wintergreen, the 3- and 5-nitro derivatives of methyl salicylate were produced and could be separated easily by their different solubility in ether.

It was known already that the action of fuming nitric acid upon 5-chlorosalicylic acid gave a nitrochlorosalicylic acid (m.p. 162°–163°) and 4-chloro-2, 6-dinitrophenol (m.p. 78°–80°) when Smith and Miss Peirce[13] showed that there was formed also in this reaction another chlorodinitrophenol, subsequently proved by others to be the 6-chloro-2, 4-dinitro isomer (m.p. 110–111°). Smith noted that the 4-chloro-2, 6-dinitrophenol, which differs from picric acid only in having a chlorine in place of one of the nitro groups of the latter, combined directly with aniline and various other bases to beautiful crystalline compounds apparently in the same way and of the same character as the analogous picrates. Ten years later[14] he extended this reaction to other aromatic bases and to anthracene, and also uncovered the interesting fact that dichloronitrophenol does not form similar com-

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[2] Edgar F. Smith, "Inaug. Dissertation," University of Göttingen, 1876; *Jahresber.*, 1877, 421; *Proc. Am. Philos. Soc.*, 17: 29, May 4, 1877.

[3] Smith, *Am. Chem. J.*, 1: 150, 1879.

[4] Smith and Keller, *J. Franklin Inst.*, 127: 311, 1889.

[5] *Proc. Am. Philos. Soc.*, 17: 68, 1877.

[6] Smith, *Proc. Am. Philos. Soc.*, 17: 68, June 15, 1877; Smith and Macchall, *Ber.*, 11: 1225, 1878.

[7] "Inaug. Diss.," University of Göttingen, 1875.

[8] *Proc. Am. Philos. Soc.*, 24: 432, November 18, 1887.

[9] *Am. Chem. J.*, 8: 95, 1886.

[10] *Am. Chem. J.*, 2: 338, 1880.

[11] *Proc. Am. Philos. Soc.*, 18: 214, March 21, 1879.

[12] *Loc. cit.*

[13] *Proc. Am. Philos. Soc.*, 17: 706, June 21, 1878; *Am. Chem. J.*, 1: 176, 1879.

[14] Smith, *J. Franklin Inst.*, 128: 156, 1889.

pounds with aromatic bases or with anthracene, from which he drew the conclusion that at least two nitro groups must be present on the nucleus of the phenol to obtain such products.

Having studied salicylic acid and its derivatives, it was quite natural that he should turn his thoughts also to the isomeric *m*- and *p*-hydroxy benzoic acids, and in 1888 and 1889[15] he reported the results of his investigations of the action of the gases from arsenic trioxide and nitric acid upon an ether solution of the ethyl ester of each of these two acids. In the case of the *meta* acid the products were the 4-nitro ester (m.p. of the free acid, 230°), a trinitro derivative and unidentified substances. From the *para*-hydroxy ester, he obtained a nitro ester carrying its nitro group *ortho* to the hydroxyl, and from this he prepared the free acid (m.p. 184–185°), certain salts and the amide.

After 1889, his interest in the organic field seems to have waned, as he became more and more engrossed in the problems of inorganic, analytical and electrochemistry, and it was only infrequently thereafter that he returned to it, to direct an occasional dissertation of some graduate student wishing to pursue his studies in that direction, like that of Seal (1895) on "The Action of Acid Amides upon Benzoin," or of Ryan (1897) on "Derivatives of Pyroracemic Acid"; or a brief research, as that with Hanna[16] entitled "Observations on Derivatives of Aconitic Acid." In pursuing his researches in the electrochemical field, organic compounds were occasionally selected for the experiments, as in the application of the electric current to accomplish the oxidation of succinic acid[17] or of toluene,[18] its action upon benzoin and benzil,[19] "The Influence of Substituents on the Electric Conductivity of Benzoic Acid"[20] and "An Electrolytic Study of Pyroracemic Acid."[21] Finally, organic compounds were tried as precipitants for the separation of inorganic mixtures as, for example, "The Action of Salicylic Acid upon the Metallic Acids"[22] and the use of "Aromatic Bases as Precipitants for Rare Earth Metals."[23]

II. INORGANIC, ANALYTICAL AND ELECTROCHEMISTRY

It was to these fields that he devoted the major part of his fifty-two years of active research and an immense amount of valuable work was accomplished.

(A) ELECTROCHEMISTRY

Perhaps his most important contributions were those he made to electrochemistry, a domain in which he was a pioneer and soon became a recognized leader of international reputation. In the hands of this master craftsman, the electric current became a tool of undreamed of usefulness and possibilities, opening up wholly new methods of analysis, separation and determination. About half of all the research papers he published were based upon new applications of the electric current. His introduction of the rotating anode together with the employment of currents of high amperage and high voltage marked a new epoch in the development of electroanalysis. His books on electrochemistry quickly became and have since remained the standard texts in this country, while the Harrison Laboratory was soon known throughout the world for its leadership in this branch of chemistry.

(B) ATOMIC WEIGHTS

The results obtained in the study of numerous inorganic compounds by the older methods and by these newly developed applications of the electric current led to the discovery of new processes of analytical separation and to the preparation of many elements and compounds in exceptional purity.

This knowledge and these highly purified products were availed of by Dr. Smith and his coworkers in new determinations of the atomic weights of the elements, those fundamental units of our science. New ratios were established with the most painstaking care and accuracy for comparison with those already in the literature.

For example, Debray had shown, in 1852, that in a current of dry hydrogen chloride, molybdic acid could be completely volatilized as the dihydroxychloride. In the Harrison Laboratory this method was used to expel the molybdic acid from sodium molybdate, leaving only sodium chloride, and also as a means of separating molybdenum from tungsten. This suggested quite obviously a study of the behavior of other metallic oxides when treated similarly, with the consequence that many proved to be volatile not only in dry hydrogen chloride but also in other gaseous hydrogen halides. Such a complete elimination of certain of the elementary components of a pure compound provided another new way of arriving at atomic weight ratios.

In addition to this method and the electrolytic one of determining these atomic weight ratios, others were invented to meet the needs of special cases.

The elements included in these studies were Ag, Cd, Hg, Sc, V, Nb (Cb), Ta, N, As, Sb, Mo, W, Se, F, Cl, Br, B and Pd, a total of eighteen, or 20 per cent. of all now known to chemistry.

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[15] *Proc. Am. Philos. Soc.*, 25: 165, September 7, 1888; *J. Franklin Inst.*, 128: 488, 1889.

[16] Hanna and Smith, *J. Am. Chem. Soc.*, 21: 381, 1899.

[17] Clarke and Smith, *J. Am. Chem. Soc.*, 21: 967, 1899.

[18] Merzbacher and Smith, *ibid.*, 22: 723, 1900.

[19] J. H. James, "Dissertation," 1899.

[20] A. Tingle, "Dissertation," 1899.

[21] G. W. Rockwell, "Dissertation," 1900.

[22] J. H. Muller, "Dissertation," 1910.

[23] Alice McM. Jefferson, "Dissertation," 1901.

As the methods employed for these important determinations illustrate admirably the type of work then being conducted in the Harrison Laboratory, it will be instructive to consider them for a few moments in somewhat more detail, to appreciate fully the resourcefulness and skill of their directing genius.

(*a*) *Electrolytic Methods*

Silver is so beautifully and so completely precipitated by the electric current that varying amounts of silver nitrate were electrolyzed in the presence of potassium cyanide, and the precipitated silver weighed. Then silver acetate and silver benzoate were substituted in turn for the nitrate. The general average of these numerous determinations as carried out by Hardin[24] gave the atomic weight of silver as 107.928. The accepted figure to-day is 107.880.

Cadmium. In 1892, Lorimer and Smith[25] dissolved cadmium oxide in potassium cyanide, electrolyzed the solution and weighed the metallic cadmium separated. The results indicated an atomic weight for cadmium of 112.055.

Four years later, Hardin and Smith[26] conducted similar experiments substituting anhydrous cadmium chloride and cadmium bromide for the oxide, and obtained a mean atomic weight of 112.045.

The average of all these determinations gave cadmium an atomic weight of 112.048. The figure now accepted is 112.41.

Mercury. Hardin and Smith also electrolyzed mercuric chloride and bromide, in the presence of potassium cyanide, obtaining with the chloride an atomic weight for mercury of 200.006, and with the bromide of 199.883. The electrolysis of mercuric cyanide in platinum dishes gave an atomic weight of 200.071, while the simultaneous precipitation of mercury and silver from a cyanide solution by the same current gave for mercury the value 199.996. The mean of all these determinations was 199.989. The accepted figure to-day is 200.61.

Palladium. The determination of the atomic weight of palladium proved to be an exceptionally difficult task. Keller and Smith[27] electrolyzed an ammoniacal solution of palladammonium chloride, plating out the metal on the silver-coated platinum dishes which served as cathodes. The atomic weight of palladium found in this way was 106.914.

Seven years later[28] Hardin heated diphenyl-palladammonium chloride in a current of hydrogen and obtained an atomic weight of 107.006 for palladium. Using the corresponding bromide, the figure was 107.036. In another series of experiments, he used ammonium palladium bromide instead, and found the value 107.00.

In 1908, Kemmerer[29] heated palladammonium chloride in an atmosphere of hydrogen and weighed the residual metallic palladium. The results won pointed to a mean atomic weight for palladium of 106.420. Palladammonium cyanide, similarly treated, yielded the figure 106.458. He also undertook to precipitate silver and palladium by the same current, using as anodes pencils of these metals, planning in this way to compare the weights of the two metals separated upon the cathodes and thus to arrive at a direct ratio between palladium and silver. The failure of the experiments was traced to the presence of palladium still in the solutions.

Later, Shinn[30] precipitated metallic palladium from an ammoniacal solution of palladammonium chloride by the addition of ammonium formate and by this method arrived at an atomic weight of 106.709 for palladium.

The atomic weight assigned now to palladium is 106.7. In the course of the reductions in a current of hydrogen, it was discovered that great care was necessary to avoid volatilization of palladium double salts and even of the metal itself, while Dr. Smith believes that the somewhat high results of the electrolytic method were not due to occlusion of hydrogen by the precipitated palladium, but to the presence of varying amounts of derivatives of quadrivalent palladium in the supposedly pure derivatives of the divalent palladium used for the experiments.

Chlorine and bromine. The quantitative determination of anions by the use of a mercury cathode and a rotating silver anode was developed to such a high degree of accuracy that Goldbaum[31] decided to make use of it for determining the atomic weights of chloride and bromine by electrolyzing the corresponding sodium halides and weighing the gain in weight of the silver anode. The results showed an atomic weight for chlorine of 35.459, and for bromine of 79.927, as over against the accepted figures of 35.458 and 79.916.

(*b*) *Methods Based Upon the Volatilization of Certain Constituents in a Current of Dry Hydrogen Halide*

Molybdenum. When normal anhydrous sodium molybdate was heated to about 300° in a current of dry hydrogen chloride, the molybdenum oxide was removed completely, as $MoO_3 \cdot 2HCl$, leaving pure

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[24] *J. Am. Chem. Soc.*, 18: 990, 1896.
[25] *Z. angew. Chem.*, 1: 364.
[26] *J. Am. Chem. Soc.*, 18: 990, 1896.
[27] *Am. Chem. J.*, 14: 423, 1892.
[28] *Jour. Am. Chem. Soc.*, 21: 943, 1899.
[29] *J. Am. Chem. Soc.*, 30: 1701, 1908.
[30] *J. Am. Chem. Soc.*, 34: 1448, 1912.
[31] *J. Am. Chem. Soc.*, 33: 35, 1911.

sodium chloride as the residue.[32] By comparing the weight of the residual sodium chloride with that of the initial sodium molybdate, an atomic weight for molybdenum of 96.08 was deduced.

A different method of attack was that of Müller,[33] who succeeded in oxidizing pure molybdenum metal quantitatively to MoO_3, and who thus arrived at an atomic weight of 96.03.

The average of these two sets of experiments is 96.055, in comparison with the official figure of 96.0.

Vanadium. McAdam,[34] in the course of his work on the vanadates, exposed sodium metavanadate to the action of dry hydrochloric acid at high temperature, which removed the vanadium and left only pure sodium chloride. The atomic weight of vanadium calculated from these experiments was 50.967, while the figure which has been generally adopted is 50.96.

Antimony.—Friend and Smith,[35] having discovered that antimony oxide could be removed completely from a mixture by virtue of its volatility in an atmosphere of dry hydrochloric acid, selected potassium antimonyl tartrate as a suitable salt for the establishment of a new ratio for antimony, and an atomic weight of 120.353 was derived thereby, as over against the present official figure of 121.77.

Nitrogen. Hibbs[36] ascertained that potassium nitrate could be converted quantitatively into potassium chloride by the action of dry hydrochloric acid at high temperature, and used this fact as the basis of a new way of learning the atomic weight of nitrogen. The value deduced was 14.0118. Another series of experiments with sodium nitrate in place of the potassium salt gave 14.0116. The general average of these two sets, 14.0117, varies but slightly from the value generally adopted, 14.008.

Arsenic. Hibbs[37] was also the discoverer of the fact that arsenic oxide could be removed completely from arsenates by the action of dry hydrochloric acid. Subjecting sodium pyroarsenate to this treatment, and weighing the sodium chloride formed, a mean value of 74.915 was found for the atomic weight of arsenic.

Ebaugh[38] conducted a similar series of experiments with silver arsenate and, from the weight of the residual silver chloride, calculated the atomic weight of the arsenic as 75.004. When the silver chloride was reduced to metallic silver, the weights of the latter obtained corresponded to an atomic weight of 74.975. He subjected lead arsenate to the action of dry hydrochloric acid, and also converted it into lead bromide, the first method giving an atomic weight of 75.022, the latter 75.00.

The general average of all these experiments led to the conclusion that the atomic weight of arsenic was not far from 74.983. The figure accepted now is 74.96.

Selenium. Lenher[39] showed that silver selenite, exposed to dry hydrochloric acid at the proper temperature, lost its selenium completely and left pure silver chloride, from the weight of which the atomic weight of selenium could be calculated. The figure arrived at was 79.325. This figure was checked by reducing the silver chloride to metallic silver, and from the weight of silver obtained the atomic weight of selenium was deduced as 79.329.

A third method used by Lenher was precipitation of selenium from an aqueous solution of its double ammonium bromide $(NH_4)_2SeBr_6$ by the action of hydroxylamine. The atomic weight so obtained was 79.285, making the mean of all these three methods 79.313, in comparison with an accepted value of 79.2.

It is appropriate to recall here that Professor Lenher never lost the inspiration imparted to him by his great teacher or his interest in the chemistry of this particular element, a field in which he soon became a recognized world leader. It is believed that his untimely death, a little over a year ago, was due either largely, or at least in part, to his continuous occupation with poisonous selenium compounds, and that his name should be added to that honor roll of those who have sacrificed their lives in the service of science.

Fluorine. Sodium fluoride was subjected to the action of hot dry hydrochloric acid gas by McAdam and Smith[40] and from the weight of the residual sodium chloride, the atomic weight of fluorine was deduced as 19.015. The accepted value is 19.00.

(c) *Miscellaneous Methods*

Tantalum. Chapin and Smith,[41] starting with tantalum pentabromide, hydrolyzed this by the addition of water, and evaporated the solution, adding small amounts of nitric acid towards the close of the evaporation to eliminate all hydrogen bromide. The hydrated oxide so formed was ignited to Ta_2O_5 and the latter weighed. From the ratio of the weight of the Ta_2O_5 to that of the $TaBr_5$, the atomic weight of tantalum was calculated as 181.80 for the mean of all determinations. The official value is 181.5.

Columbium (*Niobium*). Columbium pentachloride was hydrolyzed by Balke and Smith[42] and the colum-

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[32] Smith and Maas, *Z. inorg. Chem.*, 5: 280, 1893; *J. Franklin Inst.*, September, 1893.

[33] *J. Am. Chem. Soc.*, 37: 2046, 1915.

[34] *J. Am. Chem. Soc.*, 32: 1603, 1910.

[35] *J. Am. Chem. Soc.*, 23: 502, 1901.

[36] *J. Am. Chem. Soc.*, 18: 1044, 1896.

[37] *Loc. cit.*

[38] *J. Am. Chem. Soc.*, 24: 489, 1902.

[39] *J. Am. Chem. Soc.*, 20: 555, 1898.

[40] *J. Am. Chem. Soc.*, 34: 592, 1912.

[41] *J. Am. Chem. Soc.*, 33: 1497, 1911.

[42] *J. Am. Chem. Soc.*, 30: 1637, 1908.

bium oxide weighed. The mean atomic weight so found for columbium was 93.50.

Later, Smith and Van Haagen[43] subjected sodium meta-columbate to the action of sulphur monochloride and were thus able to eliminate the columbic oxide quantitatively, leaving pure sodium chloride as the residue, from the weight of which residue the atomic weight of columbium was deduced as 93.13. The present accepted international value is 93.1.

Tungsten. This metal and its derivatives have been the subjects of numerous important researches in the Harrison Laboratory. For the establishment of its atomic weight, eight different methods were used, namely: (1) reduction of the trioxide, (2) oxidation of the metal, (3) weighing the water formed in the reduction of the trioxide, (4) extraction of the water content of barium meta-tungstate, (5) analysis of the hexachloride, (6) analysis of iron tungstate, (7) analysis of silver tungstate and (8) determination of the water in sodium tungstate. From the figures obtained by these various processes, Dr. Smith was led to conclude that the correct atomic weight for tungsten was not far from 184.05, a figure very close to the present official value of 184.0.

Scandium. The mean value of the atomic weight of scandium, as determined by Lukens[44] by calcination of the sulphate to the oxide, was 44.33. The international tables give the preference to the value 45.1.

Boron. The determination simultaneously of the atomic weight of fluorine and of boron by Smith and Van Haagen[45] was based on the equivalent quantities of a number of different sodium salts formed by the conversion of anhydrous $Na_2B_4O_7$ through treatment with appropriate acids and repeated evaporation with methanol. From these data and the ratio $Na_2B_4O_7:2NaF$, the atomic weight of fluorine was calculated as 19.005. The borax used was prepared from pure Na_2CO_3 and H_3BO_3, the latter obtained by saponification of a carefully rectified methyl borate. Complete dehydration of borax proved difficult, but was finally accomplished by prolonged fusion. The methanol used was secured by hydrolysis of distilled methyl oxalate. The direct conversion of borax into sodium fluoride was found to be impracticable, and was attained through the formate. The atomic weight thus deduced for boron was 10.900, which is about 1 per cent. lower than the older value, and it is believed that the previous figure was inaccurate because of the retention of some water by the borax glass. The figure accepted to-day is 10.82.

(c) COMPLEX INORGANIC ACIDS

Attracted by the brilliant pioneer work of Wolcott Gibbs, and in consequence of certain observations made in extracting large quantities of tungstic acid from its ores, Dr. Smith determined to investigate certain complex inorganic acids and their derivatives. He succeeded in proving that many of those previously regarded as mixtures of isomorphs were actually distinct chemical individuals, and it was this study which caused him to announce that the great family of naturally occurring silicates was not made up of a series of salts of the several simple silicic acids, but really consisted of the alkali and alkaline earth salts of complex silicic acids, in which metallic oxides and silicic acid jointly formed the complex anion, a view which has been accepted quite generally by chemical mineralogists.

Many wholly new analytical separations and determinations were developed in the course of these studies, and a wealth of new chemical information gathered and carefully recorded.

The first of these studies was carried out by Smith and Exner[46] and concerned itself with ammonium vanadico-phospho-tungstate. This was followed up by Rogers[47] who prepared various ammonium salts of complex anions composed of the following oxides:

$P_2O_5 \cdot V_2O_5 \cdot WO_3$,
$P_2O_5 \cdot V_2O_3 \cdot WO_3$,
$P_2O_3 \cdot V_2O_3 \cdot WO_3$,
$As_2O_5 \cdot V_2O_5 \cdot WO_3$,
$As_2O_5 \cdot V_2O_3 \cdot WO_3$,
$As_2O_3 \cdot V_2O_3 \cdot WO_3$,
$P_2O_5 \cdot V_2O_5 \cdot V_2O_3 \cdot WO_3$,
$As_2O_5 \cdot V_2O_5 \cdot V_2O_3 \cdot WO_3$,
$P_2O_5 \cdot As_2O_5 \cdot V_2O_5 \cdot WO_3$,
$P_2O_5 \cdot As_2O_5 \cdot V_2O_3 \cdot WO_3$

and

$$P_2O_5 \cdot As_2O_5 \cdot V_2O_5 \cdot V_2O_3 \cdot WO_3,$$

with varying amounts of water. The complexity of such salts is obvious.

In later papers, Rogers and Smith[48] prepared and described ammonium silicoso-, titanoso-, zirconoso-, thoroso- and stannoso-vanadico-phospho-tungstates, and also ammonium vanadico- and vanadoso-tungstates.

Paralleling these studies, Balke and Smith[49] by analogous methods, obtained ammonium and ammonium silver aluminico-tungstates, ammonium, potassium and silicon bismuthico-tungstates.

Brubaker[50] added to this list the ammonium manganico-tungstate; ammonium and barium platinoso-tungstates, platinoso-phospho-tungstates, platinoso-arseno-tungstates and platinoso-vanado-tungstates.

Daniels[51] investigated the aluminico-tungstates of copper, barium, mercury and zinc; the aluminico-phospho-tungstates of ammonium, silver, barium and zinc; the aluminico-arseno-tungstates of ammonium, barium and cadmium; the aluminico-antimonio-tungstates of ammonium, silver and barium.

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[43] *J. Am. Chem. Soc.*, 37: 1783, 1915.

[44] *J. Am. Chem. Soc.*, 36: 819, 1914.

[45] *Carnegie Inst. Pub.*, 267, 1–63, 1918.

[46] *J. Am. Chem. Soc.*, 24: 573, 1902.

[47] *J. Am. Chem. Soc.*, 25: 298, 1903.

[48] *J. Am. Chem. Soc.*, 25: 1223, 1227, 1903.

[49] *J. Am. Chem. Soc.*, 25: 1229, 1903.

[50] "Dissertation," University of Pennsylvania, 1904.

[51] *J. Am. Chem. Soc.*, 30: 1846, 1908.

Further contributions were made by Blum[52] by the preparation and investigation of various phospho-vanado-molybdates.

This brief outline will suffice to give some idea of the labyrinthic character of this chemical jungle into which he penetrated so boldly and the difficulties of blazing clear trails therein.

In addition to the elements studied in connection with these complex inorganic acids and atomic weight determinations, he conducted investigations of numerous others, notable among these being such rarer ones as Be, Cs, Ge, In, Rb, Rh, Ru and Tl.

The field of analytical chemistry was enriched by many new methods of separation and determination as well as by critical studies of methods already in vogue.

III. HISTORICAL CHEMISTRY

Great as have been Dr. Smith's contributions to electrochemistry and to the inorganic chemistry of the rarer elements, they are equaled or surpassed by the service he has rendered as historian of American chemistry, the field to which he devoted the riper years of his rich life.

Within the past two decades, no one has made so many or so important contributions to this field as he, or shown superior literary gifts in the presentation of his material; and in saying this I am not unappreciative of the admirable publications of Thomas Cooper, Venable, Moore, Stillman and others. His facile pen and clever characterizations have made these chemists of previous years to live and breathe again, and their noteworthy accomplishments, as well as their foibles and fancies, are described in such a natural and interesting manner that the narrative flows on smoothly and delightfully. Many of the chemists portrayed so charmingly and so vividly by him had been "overshadowed, neglected, forgotten."

Separate books, brochures or articles have been published by him concerning the following chemists: Theodore G. Wormley, Jr. (1897), Robert Empie Rogers (1905), George F. Barker (1907), Fairman Rogers (1909), Robert Hare, an American chemist (1917), James Woodhouse (1918), James Cutbush (1919), Franklin Bache (1922), James Curtis Booth (1922), Samuel Latham Mitchill (1922), Charles Baskerville (1923), Jacob Green (1923), Matthew Carey Lea (1923), Martin Hans Boye (1924), John Griscom (1925), James Blythe Rogers (1927), Priestley in America (1920), Priestleyana (1922) and the Priestley Medal Lecture (1926).

More general treatises, written wholly or largely from the historical point of view, were: "Chemistry in America" (1914), "Men of Science from the Keystone State" (1914), "Chemistry in Old Philadelphia" (1918), "The American Spirit in Chemistry" (1919), "Progress of Chemistry" (1921), "Our Science" (1922), "A Half Century of Mineral Chemistry in America, 1876–1926" (1926), "Observations on Teaching the History of Chemistry" (1926), "Bromine and its Discoverers, 1826–1926" (1926), "Early Science in Philadelphia" (1926), "Fragments Relating to the History of Chemistry in America" (1926), "A Look Backward" (1927), "A Glance at the Early Organic Chemistry of America" (1927) and "Old Chemistries" (1927).

The commonwealth of Pennsylvania, and the municipality of Philadelphia in particular, are especially in Dr. Smith's debt, for in these historical publications he selected preferably as the subjects of his study those whose activities had centered in this city or state. He has preserved in immortal classics those great figures in science whose life work has played so large a part in the progress of our country.

> The riches of the commonwealth
> Are free, strong minds, and hearts of health;
> And more to her than gold or grain
> The cunning hand and cultured brain.

He was deeply concerned that the public should appreciate America's part in the advancement of chemistry and that succeeding generations of chemists should be familiar with the pioneer work of their predecessors; for example, that it was in America that the oxyhydrogen flame was discovered by Robert Hare in 1800; that potassium first was isolated here from its carbonate by heating the latter with lampblack, in 1808; that, in 1820, an electric furnace was constructed over here in which carbide, graphite and metallic calcium were produced; that the use of a mercury cathode in the electrolysis of metallic salt solutions originated with us; that we were the first to prepare chloroform by the interaction of alcohol and hypochlorite, and that the Chemical Society of Philadelphia, founded in 1792, was the first organization of its kind in the world.

It is a source of the deepest satisfaction and the sincerest congratulations that Mrs. Smith has presented to the University of Pennsylvania the splendid collection of historical books, documents, letters, photographs and other memorabilia collected by her husband, and that they are to remain permanently, as a Museum of Chemical History, in that office where so much of his life was spent. The University of Pennsylvania has come into possession of what is undoubtedly the finest collection of its kind in this hemisphere and one of the best in the world.

It is peculiarly fitting that his office, so familiar to all his friends and where he had gathered about him

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[52] *J. Am. Chem. Soc.*, 30: 1858, 1908.

those things which brought him the greatest pleasure, thus becomes a shrine to which frequent pilgrimages will be made by all American chemists who cherish the memory of those who have been the chief builders of their science, as well as by the many who knew and loved the quiet, unassuming, generous comrade who was its ornament and its chief attraction.

Somewhere in that museum there should be displayed prominently the classic lines of Philip James Bailey, which seem to me to sum up so accurately and so beautifully the principles which guided the life of Edgar Fahs Smith:

We live in deeds, not years; in thoughts, not breaths;
In feelings, not in figures on a dial.
We should count time by heart-throbs. He most lives
Who thinks most—feels the noblest—acts the best.
Life's but a means unto an end—that end,
Beginning, mean, and end to all things—God.

Instead of placing a wreath upon my friend's tomb, I am bringing as my tribute something which I am sure will please his spirit far more, and I hand to you, therefore, Mr. Provost, this ancient official order, dated Paris, December 24, 1791, for the payment of salaries and other expenses of officers of the Gendarmerie Nationale, signed by the great Lavoisier himself, the father of modern chemistry, as Commissaire of the National Treasury. It was secured by me in Paris a few years ago, and I know of no more worthy resting place for it than in the Smith Museum of Chemical History.

MARSTON TAYLOR BOGERT
COLUMBIA UNIVERSITY

SCIENTIFIC EVENTS

A BRITISH NATIONAL RADIUM FUND

ON April 16 the British Chancellor of the Exchequer announced that the government had undertaken to contribute out of public money towards the purchase of radium, on a basis of £1 for every £1 otherwise subscribed, up to a limit of £100,000. *The British Medical Journal* reports that a public appeal for £150,000 (making £250,000 in all) to form a "National Radium Fund" has now been set on foot by leaders of the medical profession acting in concert with laymen prominently associated with the work of hospitals and cancer research. The purpose and scope of the fund were indicated in a letter published in the *Times* of April 29, over the signatures of Sir John Rose Bradford, Lord Moynihan, Lady Barrett, Sir E. Farquhar Buzzard, Lord Dawson of Penn, Dr. Robert A. Fleming, Lord Gorell, Sir Thomas Horder, Lord Knutsford, Mr. J. P. Lockhart-Mummery, Sir Ewen J. Maclean, Dr. J. M. H. MacLeod, Mr. Alexander Miles, Lord Reading, Sir Humphry Rolleston, Sir Arthur Stanley, Lord Stanmore, Sir StClair Thomson and Sir John Bland-Sutton.

The money obtained in this way, together with that contributed by the government, is to be held by a body known as the National Radium Trustees, who will buy therewith and hold radium for use by an administrative body of experts known as the National Radium Commission. The trustees are being constituted by the government in accordance with one of the recommendations made by the Radium Subcommittee of the Committee of Civil Research, but with two additional medical members to be nominated from their own number by the Radium Commission. The composition of the latter body has been modified so as to ensure adequate representation upon it of those familiar with the use of radium in medical practice, and its membership has been increased from nine to eleven. The commission will thus consist of a chairman, appointed by the trustees; six members, appointed by the trustees from a list of names drawn up by the titular heads of the medical profession, and four members nominated, respectively, by the Minister of Health, the Secretary of State for Scotland, the Medical Research Council and the Department of Scientific and Industrial Research. The general effect of these changes in the administrative framework of the scheme put forward by the Radium Subcommittee is summed up in the letter published on April 29: "The radium will be bought and held by a body of trustees which has the confidence alike of His Majesty's government and the medical profession. It will be administered by a commission which will contain an effective majority of members representing the skilled and experienced workers on the staffs of the voluntary hospitals."

The national appeal for radium is being made conjointly with a special appeal by King Edward's Hospital Fund in aid of the hospitals in the metropolitan area as a thank-offering for the king's recovery, the nucleus of the latter project being 100,000 guineas offered by an anonymous benefactor. Lord Donoughmore is acting as treasurer of the combined appeals, and arrangements have been made by the King's Fund so that contributions earmarked for the purchase of radium for the needs of the whole country will be applied to that purpose through the National Radium Fund.

COOPERATION IN FISHERIES RESEARCH

THE oceanographic laboratory at the Peabody Museum of Yale University will undertake a research program in cooperation with the U. S. Bureau of Fisheries. According to this program, the Bingham