

the notes in the **Journal of Industrial and Engineering Chemistry**. At Illinois State and municipal publications on water supply problems are largely available in the **Water Survey** collection, while others are in the **Municipal Reference** library in Lincoln Hall.

If the engineering phase of a problem is emphasized, the **Engineering** library with its special indexes and serials is the more satisfactory; here too is found most of the literature upon mining, though the strictly geological works are in the **Natural History** library. Every special industry of any size has its own serials, as well as books, for example, ceramics, which has here its own library. However, many of these serials are abstracted in the chemical abstract serials, i. e. both those upon general and the ones dealing with applied chemistry, so that these reference serials must often be consulted in addition to the special ones, to collect all the literature upon a topic.

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## LECTURE 13

### THEORETICAL AND PHYSICAL CHEMISTRY, INCLUDING COLLOIDS: BOOKS

The division between the first and second is not always made by authors, but the books noted will be classed where their authors place them; the chemistry of colloidal substances may be partly both, but the books will be discussed separately for convenience. We have then to consider:

- A. Works on theoretical chemistry
  1. Historical
  2. General
  3. Special
  
- B. Works upon physical chemistry
  1. General
  2. Laboratory manuals
  3. Special
  4. Tables of data
  
- C. Chemistry of colloids
  1. Comprehensive works
  2. Briefer, semi-popular books
  3. Works on special phases

With respect to the practical value of the theoretical field, **Mendeleef** says: "By summoning adherents to the work of theoretical chemistry, I am convinced that I call them to a most useful labor, to the habit of dealing correctly with nature and its laws, and to the possibility of becoming truly practical men." **Nernst** describes it as the theoretical treatment of practical processes. Given a logical, orderly arrangement of facts observed and laws deduced in the study of chemical changes, with a historical examination of the chemical ideas and theories, we find in theoretical chemistry a presentation of the main lines along which chemistry has advanced.

### A. 1. *Historical*

Lothar Meyer's *Moderne Theorien*, Ed. 1, 1863, was written to explain and justify theory in chemistry to the workers in other sciences and to "prepare the way for physical chemistry". More recent is M. M. P. Muir's *History of chemical theories and laws*, 1907; he discusses the history of attempts to answer these questions:

What is a homogeneous substance?

What happens when homogeneous substances interact?

Freund in her work takes up the study of chemical composition; "I have tried to show how the empirical knowledge has been obtained, what the initial discoveries were, and how they were established;" the new edition, 1921, has the title, *The experimental basis of chemistry*.

### A. 2. *General works upon theoretical chemistry*

Brief discussions of theory are given in most of the general texts, particularly the larger ones. Wilhelm Ostwald has such a section in his *Lehrbuch*, Mendeleef discusses the topic; one of the larger early works was that by H. Buff, H. Kopp and H. Zaminer, in which Kopp wrote the theoretical chapter; later, Ed. 2 of this was published as vol. 1 of Ed. 4 of Graham-Otto's *Lehrbuch der Chemie*, 1863. One of the best texts now is the most recent edition of Nernst, first published as chapters on theory in Dammer's *Handbuch der anorganischen Chemie*, 1892. This work called by its author then "a brief presentation of the present state of physical chemistry and its most important aims" had for title of the first separate edition, "Theoretische Chemie" and was described as a theoretical treatment of chemical processes for the investigator of physical chemistry. Wilh. Ostwald's *Prinzipien der Chemie*, 1907, appeared in English, 1909, as *The fundamental principles of chemistry*, an introduction to all text-books of chemistry; a similar work in French, also translated into English, is Copaux, *Introduction à chimie générale*, 1919. The new book by R. M. Caven, *The foundations of chemical theory*, 1920, is somewhat similar for "the general reader who wishes to know what chemistry really means"; it is less technical than the ones by Ostwald and Copaux, i. e., the reader is not expected to know as much about the science.

### A. 3. *Special works on theory*

These may be separate works, but considerable material is given in, for example, such works as Meyer and Jacobson's *Lehrbuch der organischen Chemie*, and the first volume of Freund's *Textbook of inorganic chemistry*. Werner presents in his *Neuere Anschauungen*, his ideas upon the structure of the inorganic compounds; Henrich, *Theorien der organischen Chemie*, new edition, 1912, presents the views then held as to organic chemistry. Cohen, *Organic chemistry*, 3 vol. Ed. 2, 1919, gives theoretical organic in English; Ed. 3, is 1921. The two volumes by Stewart, *Recent advances in organic*, and in inorganic and physical, in the fourth editions now, 1921, give besides statements on recent progress the current ideas.

## B. *Works upon physical chemistry*

Physical chemistry is claimed with some reason by the mathematician, the physicist and the biologist, while the engineer sees it from his own viewpoint; we may assume it to be chemistry, used in the other branches of science. Descriptions of it vary. Ramsay says: "When the laws or generalizations regarding properties of matter depend not merely upon the masses or rates of motion of the objects concerned, but also upon their composition and chemical nature, their consideration falls under the heading 'physical chemistry' ". This includes nearly every scientific problem in science.

Kekulé in the early seventies told his classes at Bonn that chemistry had reached its limit, the dead center, with no prospect then visible of new advances. This was shortly after disproved brilliantly by one of his own students, van't Hoff, who by the development of the ideas of space arrangement and structural formulas, gave a new field to the organic chemist.

Stange, in *Die Zeitalter der Chemie*, 1908, says "Chemistry by the introduction of physical methods, calculation, measurement, weighings, has been made, in so far, an exact science, and the influence of physics here must not be underestimated; however, that relations exist between the chemical and physical properties of substances, was known long before the time of Lavoisier."

Differentiation of physical chemistry from physics and general chemistry began about 1830, though much work done before that forms an important part. Hermann Kopp, the historian of chemistry, and from 1851-71 one of the editors of the *Annalen der Chemie* was one of the early workers in this field, as shown by the chapters in the book by Buff, Kopp and Zamminer, 1857, as well as by his papers in the serials.

### B., 1. *General works, comprehensive*

The most recent in English is the new 3-volume edition of W. C. McC. Lewis's *System of physical chemistry*, and at present this is the most comprehensive work in English also. In German the new large one is K. Jellinek, *Lehrbuch der physikalische Chemie*, nominally in four volumes, began in 1914 and not completed; it is to be, the author says, a comprehensive reference text "for mature students of physical chemistry, physics and chemistry and for investigators." Nernst, *Theoretical chemistry*, in the most recent English version (1916) of succeeding German editions is perhaps the most satisfactory one-volume work for the larger part of physical chemistry.

One man deserves special attention, J. H. van't Hoff, 1852-1911, native of Holland where he had his college training, and later a student under Kekulé at Bonn and Wurtz in Paris; he was professor of chemistry at Amsterdam 1878-95, and at Berlin 1896-1911. Though he refused to be described as a physical chemist, his lectures, *Vorlesungen über theoretische und physikalische Chemie*, Ed. 2, 1903, in three small volumes, give some very clear and valuable material; these have been published in English also. He was described, when given the degree of LL. D. at the University of Chicago in 1902, as "Founder of the theory explaining the space relations of atoms, master in the field of dynamic chemistry, investigator of renown in the domain of the modern theory of solutions."

The smaller works, usually in one volume, upon physical chemistry are numerous; perhaps the newest is Washburn's Principles of physical chemistry, Ed. 2, 1921, which is emphatic on the mathematical side of the subject; Walker, Introduction to physical chemistry, Ed. 8, 1919, is larger, with more descriptive matter and discussions; the newest edition of Morgan's Elements of physical chemistry here is Ed. 5, published 1914; Lincoln's book, 1919, is more elementary. Older ones include Bigelow, Jones, Ramsay, Reychler, and Speyer, the last three published before 1900, and not up to date now.

The two principal series in English are (1), Textbooks of Physical Chemistry, edited by Ramsay; consisting of about twenty volumes on the subject as a whole and its divisions; (2), Monographs on Inorganic and Physical Chemistry, edited by Findlay, containing about ten volumes at present, on topics from osmotic pressure to rare earths; the series, Monographs on Physics, edited by J. J. Thomson, about ten volumes to date, is nearly as much physical chemistry as physics.

The German series, Handbuch der angewandten physikalischen Chemie, begun in 1905, is edited by various men, while the volumes are all on some more or less applied phase of the subject; it includes German editions of Findlay's Phase rule, and Desch's Metallography.

### B.2. *Laboratory manuals*

Here again, almost every teacher has written a book; some of these are Getman, Laboratory exercises, 1908; Pring, same title, 1911; Gray, Manual of practical physical chemistry, 1914; and perhaps the best now, Findlay, Practical physical chemistry, Ed. 3, 1914.

### B.3. *Special works*

Here may be included, Mellor, Chemical statics and dynamics, Ed. 3 being of 1921; also his Higher mathematics for students of chemistry and physics, Ed. 4, with Partington's similar work and his Textbook of thermodynamics with special reference to chemistry, 1913. Translated from the German are these: Nernst, Experimental and theoretical applications of thermodynamics to chemistry, 1907; Sackur, Textbook of thermo-chemistry and thermodynamics, 1917; Planck's Lectures on theoretical physics, 1915; his lectures on thermodynamics are only in German here, Ed. 3, 1911. Weinstein's three volumes on thermodynamics were finished in 1908; the Lehrbuch der Thermodynamik of van der Waals began the same year. Thomsen's Thermochemistry was published as one of the Ramsay series, Textbooks of physical chemistry, in 1908; Findlay's Phase rule, and Desch's Metallography, first published there, have been translated from English into the German series Handbuch der angewandten physikalischen Chemie. Jellinek, Physikalische Chemie der homogenen und heterogenen Gasreaktionen, 1913, is only in German. Höber, Physikalische Chemie der Zelle und Gewebe, Ed. 3, is 1911; Koranyi and Richter, 2 vol. in German, discuss the application of physical chemistry to medicine; Robertson, Physical chemistry of proteins has Ed. 1 in German, 1912, but Ed. 2, 1918, is in English; McClendon, Physical chemistry of vital phenomena, appeared in 1917.

#### B, 4. *Tables of data*

Elaborate tables are found in Landolt-Börnstein, *Physikalisch-chemische Tabellen*, Ed. 4; the tables, *Recueil de constantes physiques*, published by the Société française de physique, 1913, give newer material; both these are supplemented by the Annual Tables, v. 1-5 (v. 4-5, 1921) that present new data for the years 1910-20. The Physico-chemical Tables, 2 vol., edited by J. C. Evans, in 1911, are more limited in scope. Comey and Hahn, *Dictionary of solubilities: inorganic*, Ed. 2, 1921, seems to be well prepared; Seidell, Ed. 2, includes organic and inorganic compounds but does not take up many uncommon substances.

The smaller works are, Van Nostrand's *Chemical Annual*, Atack and Whitney's *The Chemists' Yearbook*, *Chemiker-Kalender*, but these give data for common substances, rather few in number.

#### C. *Chemistry of colloids*

The term colloids was first applied by Graham in the sixties to various non-crystallizable, glue-like compounds; matter in this state is characterized by lack of definite form, and fineness of division, with peculiar physical and chemical properties. Various theories have been offered as explanatory, designating it as due to dispersion, suspension, solution. Wolfgang Ostwald, in 1906 proclaimed it as "the chemistry of the twentieth century".

Cassuto, 1911 says: "Investigation of colloids depends upon the solution of this problem (first proposed by Wolfgang Ostwald)—'To determine in what manner the chemical and physical properties of a substance depend upon the degree of its dispersal'—", meaning by dispersal the fineness of division and degree of separation from each other in space of these most minute particles.

The newest book here is the volume, part translation, part original, Zsigmondy and Spear, the latter being the translator, and author of the second part, dated 1917. The first English edition from the third German one of Wolfgang Ostwald's book is *Handbook of colloid-chemistry*, 1915; Taylor, *Chemistry of colloids*, written as a textbook, is also of 1915. A very satisfactory brief treatment in German is *Der kolloide Zustand der Materie*, by Leonardo Cassuto, 1913, written in 1911; Zsigmondy's *Colloids and the ultramicroscope*, published in German in 1905, appeared in English in 1909; works older than that are to be used with caution. E. K. Rideal is preparing a book on *Chemistry of colloids*, that should be of much value, as it will present the results of recent work.

#### C, 2. *Briefer works*

Very small books, originally in German, are those by Pöschl, 1916, in English; by Rohland, English, in 1913; the one, *An introduction to the physics and chemistry of colloids*, Ed. 3, 1919, by Emil Hatschek is, apparently, the best of its size. The book made up of the lectures by Wolfgang Ostwald in the United States in 1914 was published in 1917, and should form a good introduction to the subject.

#### C, 3. *Works on special phases*

Perrin's studies on the Brownian movement of particles first published in the *Annales de chimie*, are now available in book form in both English and German. Bemmelen's volume of researches upon absorption and soil colloids has

an introduction by Wolfgang Ostwald. Solid solutions are discussed by Bruni, and inorganic colloids by Lottermoser in v. 6 of Ahren's *Sammlung*, 1901. Arrhenius adds to his Theory of solutions, 1913, a 12-page list of select references on colloids. Muller in *Zeitschrift für anorganische Chemie* gives in 1904, a select bibliography of 356 titles on colloids. Burton, *Colloidal solutions*, 1916, is one of the English series, *Monographs on Physics*.

Colloids in relation to biology and medicine are taken up by Beechhold, 1912, (translation of second German edition is 1919), by Pauli in his work on muscles, 1912, by Freundlich in his *Kapillarchemie*, Ed. 2, published in 1914, and in the two volumes by Koranyi and Riechter on physical chemistry and medicine, 1907-09. Arndt, Ed. 2, 1911, gave something upon uses of colloids in the industries; Taylor, 1915, discusses it briefly, and more recent material is in the second part of Zsigmondy and Spear, *Chemistry of colloids*, 1917. The newest here is Bancroft's *Applied colloid chemistry: general theory*, Ed. 1, 1921. The possibilities particularly as regards clays for ceramics and in soils, the preparation of semi-liquid fuels, and in connection with tanning, and dyeing, furnish a large field for investigation that has been scarcely touched.

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## LECTURE 14

### THEORETICAL AND PHYSICAL CHEMISTRY, INCLUDING COLLOIDS: SERIALS

Articles upon chemical theory appear in all the various serials, particularly those on general chemistry and those on physical chemistry; however such articles are widely scattered through all the chemical serials and seem likely to continue thus. Use for finding any such papers the general abstract, review and index serials, looking up the specific topic, and, if necessary, collateral topics in order to make sure that no entries are overlooked.

Serials upon physical chemistry, or rather those containing papers upon it may be grouped thus:

- A. Serials containing chiefly original papers
- B. Reference serials
- C. Serials upon the chemistry of colloids

#### A. *Serials containing chiefly original papers*

The statement made for theoretical chemistry holds good here to some extent; much of the very early work was published in the *Annalen der Physik*, often referred to under the names of its various editors as Poggendorff's or Wiedemann's *Annalen*; this has many series and the approximate date is needed generally to identify the articles. Due to Kopp's editorship, a number of papers are in the *Annalen der Chemie*, 1850-70.

The first serial for physical chemistry alone is *Zeitschrift für physikalische Chemie*, started in 1887 by Wilhelm Ostwald and J. H. van't Hoff; quoting an eminent physiologist they termed this division "the chemistry of the future". Until 1906, besides book reviews this had some abstracts. Indexes are annual

though sometimes several volumes are covered; two collective indexes cover the period to 1906.

The second, *Journal of physical chemistry*, began at Cornell University in 1896, and had abstracts till the *Chemical Abstracts* commenced in 1907; the annual volume has nine numbers, none being published in July, August, and September.

The next in point of time, *Journal de chimie physique*, founded at the University of Geneva, Switzerland, was started "to provide a central place of publication", and the articles are in the French language. After vol. 4, 1905, the abstracts were reduced to a subject-index for the current literature of physical chemistry. There is a collective index for vol. 1-10.

The Russian journal of physical chemistry (this is said to be on file at the University of Minnesota) has contained some important papers; some of these were reprinted in part or wholly in the *Journal für praktische Chemie*.

### B. *Reference serials*

Here we must depend chiefly upon the general abstract, index, and review serials. There are two special ones, neither very comprehensive.

The *Biophysikalisches Centralblatt* was published in separate volumes, 1905-10; after that the articles were included by the *Zentralblatt für Biochemie and Biophysik*; this changed its name in 1919, and absorbed two others, becoming *Berichte über die gesamte Physiologie und experimentelle Pharmakologie*.

The *Physikalisch-chemisches Centralblatt*, 1904-09, was continued as *Fort-schritte der Chemie, Physik and physikalischen Chemie*. This began publication at Darmstadt as "an international abstract serial for physical chemistry and the debatable land between chemistry and physics." Series 1 was chiefly abstracts, with annual index; series 2 is of the review form, and has had one collective index for v. 1-5.

### C. *Serials upon the chemistry of colloids*

Much of the earlier work was published in the *Zeitschrift für physikalische Chemie*.

There is at present only one, with a supplement in which are published papers of considerable length. R. Dittmar edited volume 1 of the *Zeitschrift für Chemie und Industrie der Kolloide*, 1906, at Graz; the next year, the place of publication was Leipzig, Wolfgang Ostwald became editor and has continued to be, except for an interval of army service, when it was carried on by members of his family. The name has varied a little, but was changed in 1913 to *Kolloid-Zeitschrift*. There are some abstracts in the *Kolloid-Zeitschrift*, but no attempt is made to include all the articles in print; the indexes so far have been rather inadequate, and for some volumes here, are lacking. The supplement, begun in 1909, is called *Kolloid-chemische Beihefte*, and contains original articles only; it is under the same editorship. To obtain all references for a topic in the chemistry of colloids, one must use the general reference serials, and it is desirable to consult two at least, as the subject headings under which articles are placed may vary.