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THE CROSS-FERTILIZATION OF THE SCIENCES.

OPENING ADDRESS FOR THE WORLD'S CONGRESS OF CHEMISTS, SECTION OF PHYSICAL CHEMISTRY.[1]

BY ROBT. B. WARDER, WASHINGTON, D. C.

IT gives me pleasure to take my turn, while introducing the subject of physical chemistry, to welcome our guests from far and near, and to thank you for the interest shown throughout the week.

Science has been defined as *knowledge classified*; and there are philosophers whose special anxiety it is to find pigeon holes duly arranged in rank and file, where the several classes of facts can be stowed away in order like the various genera and species of a fauna or flora. But the boundaries of a science, as of a biological species, can not always be defined. Hybridism in knowledge, as in husbandry, yields offspring of special value. The late Dr. Gray was wont to exhibit the wonderful natural contrivances of the orchids, by which each pistil should not be fertilized by its own pollen, but by that from some other flower. To this habit no doubt is largely due that wonderful development of form and color. The practical stock-raiser or horticulturist, with an ideal sheep, or cotton-plant, or chrysanthemum, in his mind, proceeds to select and unite the parents, combining the several desirable characteristics, so that the product more and more closely approaches his ideal.

So also in the evolution of science, the most striking developments appear in the judicious combination of distinct parents.

[1] Read August 26, 1893.

The laws of planetary motions lay hidden, until mathematical analysis under Kepler and Newton joined hands with the long record of nightly observations. In more recent times a "new astronomy" has arisen, counting its parentage from the old astronomy on one side and from physics on the other. The presidential address on orology, which was read at Madison last week, sought to trace the history of the mountain range, by uniting the studies of mathematical physics with stratigraphical and dynamical geology.

It is especially true in the problems of daily life, that conclusions must be reached, not belonging to any one line of investigation, nor to two, but to nearly the whole range of science. A dairyman, for example, with one hundred acres of ground, wishes to produce as many pounds of butter as possible. Geology may contribute to the interpretation of his soil; biology is directly concerned with his pasture and his herd; chemistry and physics deal with the processes of feeding and manufacture; while the best market for the butter and utilization of by-products must conform to the laws of political economy.

It is needless to multiply such illustrations. The manufacturer and the engineer can never say of any kind of science, "That will be of no use to me." A life-time may be spent luxuriating in the riches of any one science (if one has leisure for such luxury), but the most important and fruitful outcome in our day is usually the product of different sciences.

The fertility of such union is especially noteworthy in chemistry and physics. Look at some examples from the papers just read in this Congress. Professor Prescott, in discussing advances in analysis,[2] reminds us of optical and thermal determinations, and of those based on solubility, capillarity, etc. The chemical world, he says, is alive to the new physical chemistry, and none are more indebted than analysts. The same fact is further illustrated in the distinguishing properties of olive oil as set forth by Professor Rising. The proper adjustment of potential and current is required in electrolytic separations;

[1] By Professor Joseph Le Conte, retiring President of American Association for the Advancement of Science.

[2] *This Journal*, 15, 376–379. See also "Methods of Testing Fats and Oils," by Milliau, *this Journal*, 15, 153–172.

and the speed of chemical action (varying with the temperature) must be responsible for many discrepancies in the estimation of citrate-soluble phosphates.

Passing to organic chemistry, the question introduced by Professor Witt,[1] "Why make so many dye-stuffs?" led us to the absorption (or subtraction) theory of the mixture of pigments, as distinguished from the addition theory, applicable to physical colors. Still more singular is the extension of the theory of solution to cover the nature of dyed wool, silk, or cotton, where the dye must be selected with due regard to its solubility in the fiber to be colored. In this industry, conditions of chemical equilibrium are especially important. Bright colors with a high degree of chemical energy may sell well the first season, but in the end are sure to disappoint all parties concerned.

The scientific and statistical basis for the assessment of farms has been discussed by Professor Thoms.[2] The principles of political economy involved may be referred to those officials who require the farmer to pay more than his share of tax, but the subject of values was seen to be closely linked to both the chemical composition and the physical properties of the soil.

To review yesterday's papers on technological chemistry and to point out all the fruits of cross-fertilization between chemistry and physics, would tax your patience too far. Some of the more striking illustrations are found in the apparatus for rapid removal of latent heat from vapor of nitric acid as described by Dr. Hart;[2] the judicious selection of a solvent for the electrolysis of alumina, and the economical preparation of a disinfecting fluid by electrolysis of sea water[2] as discussed by Professor Langley.[3]

In all the operations and needs of daily life, we find chemical substances adapted to their several purposes in virtue of their physical properties. For many years the discussion of density, solubility, optical, thermal, and electrical properties,

1 "Artificial Coloring Matters," *this Journal*, 15, 456–463.

2 Not yet published.

3 Other industrial applications were presented to the Section of Physical Chemistry in a paper, "On Apparatus for Promoting the Interaction of Liquids and Gases," by Professor George Lunge, *this Journal*, 15, 361–374.

crystalline form, etc., were grouped under the name of chemical physics. A vast store of facts was accumulated, of somewhat empirical character, like a valley of dry bones. A new life has appeared with the recent developments of the doctrine of energy. The old name takes a new form. The old numerical data have been greatly extended with the addition of broad generalizations. Physical chemistry is the order of the day. But what is this physical chemistry? And what is it for?

Nearly twenty years ago, a chemical student in Berlin was using costly organic materials by the hectogram or kilogram to prepare some new compound in quantities barely sufficient for analysis. Looking forward he dreamed of some general laws yet to be discovered by which it might be known whether a given blackboard equation would or would not find its counterpart in the laboratory without the necessity for such expenditure of time and material to prove each point. Are we not to-day somewhat nearer the realization of that dream?

We form a plan and want to know whether it will work. We put it into execution and find it works in part. There are losses, sources of waste, that must be overcome before the process can fulfill our wishes. We now ask, not merely, Will it work? but How far will it work? And this is the very question in its general form which occupied the mind of J. Willard Gibbs about the same time that the student was indulging in his reveries. The result was a paper, "On the Equilibrium of Heterogeneous Substances," a paper bristling with differentials and integrals, with the merit of applying equally to physical and to chemical operations. It presents the fundamental principles of change or non-change in general terms, requiring only the proper application of minor premises to yield the particular facts desired. Experiment is still required to find the minor premise, but rapid progress has been made.

This is abundantly shown by Professor Ostwald's last volume on chemical energy, covering more than 1,100 pages. This distinguished author has very kindly sent us a brief review of the leading principles in the paper next on the program.[1] Sooner or

[1] "On Chemical Energy," *this Journal*, 15, 421–430. The translation was kindly made for the Congress by Mr. Wm. H. Krug.

later this new leaven will doubtless be felt in agriculture, in technology, and in biology. Already we find a special chair of physical chemistry in Cornell University, from which we shall hear further.[1] Other universities may do well to recognize this middle field in fixing the limits of the several professorships. The time is at least ripe for a more general acquaintance with the subject.

THE COMPOSITION OF AMERICAN CHEDDAR CHEESE.[2]

BY L. L. VAN SLYKE.

IN the course of a large number of experiments made in the manufacture of cheese at the New York (Geneva) Experiment Station, a careful study was made of the composition of the cheese manufactured. Knowing the composition of the milk and of the resulting cheese, it was possible to trace the influence of the composition of the milk upon the composition of the cheese. The results given are for the green cheese as it came from the press. The composition of the cheese in a cured or marketable condition can be calculated by allowing for a loss of water varying from four to eight per cent. The first thoroughly reliable analyses of American cheese by an American chemist were published by Dr. Caldwell in 1877, but these were not large in number, and the composition of the milk was not given or known.

The points relating to the composition of cheese upon which I desire especially to dwell briefly are the following:

1. Water and solids.
2. Fat.
3. Casein and albumen.
4. Relation of fat to casein in cheese made from normal milk.
5. Relation of fat to casein in cheese made from skimmed milk.
6. Relation of fat to casein in cheese made from milk containing added cream or other fat.

[1] "The Fundaments of Chemical Theory," by Professor J. E. Trevor, *this Journal*, 15, 430–448.

[2] Read before the World's Congress of Chemists, August 24, 1893.