fitted to lead to positions of an executive nature in connection with industrial enterprises, and in the administration of public works. Everywhere will be demanded expert skill, sound judgment and broad views, primarily because these will be found to be economical. The entire class of men that a recent writer has called 'mattoids,' the ill-trained, narrow and egoistic, will be pushed out because their service is costly.

There are two tendencies in the present-day engineering education that are, in my judgment, opposed to the desirable result. First, a tendency to crowd too much of the foundation work back upon the preparatory school, already overloaded. This Society's Committee on Entrance Requirements has advocated a standard which is high enough. Second, the allowing of technical subjects to crowd the fundamental general ones from the college course, in a vain attempt to do what from the very nature of the case cannot be done, make an engineer by college study. The result of this in some institutions is further seen in too early a differentiation between the various engineering courses; so that, for instance, the civil student knows nothing of applied electricity and the electrical student nothing of surveying, while neither has a chance to acquire a taste for literature.

The whole problem is an involved and complicated one, but there is a way out that must be found if the engineer is to fill the important place that awaits him. One part of the solution will be probably found in a refining of the methods of instruction, so that better results may be reached in the same time. In the end, however, the writer thinks that there must come a deeper sense that after all life is long, that it should be taken with more of deliberation, and that it is the end that is important, rather than the beginning. The feverish rush and haste to be earning must be replaced by a recognition of the real necessity for a full rounded-out preparation if the largest and best service is to be given. Then the student will be glad to spend the one or two extra years in college that may be demanded. The wise student now will do this without its being required.

The Chief Justice of my own State has said, "The spirit of an age is that which makes finally for the happiness of the race. I have absolutely no fear as to the final end of things, nor as to the steps and incidents of evolutionary development. The aspirations, the great universal possessions of a people, can never move them to other ends than their happiness and good. The spirit of this age is commercial enterprise and conquest, and as to it I have an unspeakable conviction that it will, as the spirits of other ages have done, work itself into forms and institutions of beauty and eternal worth to men."

It is largely through the engineer that this is to be done. The finest result requires the most skilful labor; the noblest workman demands the most fitting training.

Herein lies our responsibility!

FRANK O. MARVIN.
UNIVERSITY OF KANSAS.

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*PHYSICAL CHEMISTRY.**

As I am to deliver in the course of the next few days a series of lectures upon some parts of physical chemistry in their details, I should like to use this educational conference as an occasion for presenting an introduction to my lectures.

I add at once that one of our best modern historians, Ladenburg, in his 'Development of Chemistry in the Last Twenty Years,' sustains that the more and more prominent position of physical chemistry characterizes the development of our whole chemical

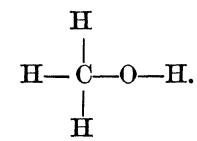
* An address given at the decennial celebration at the University of Chicago, published in the *University Record*.

science during the last twenty years. Let me briefly trace how this physical chemistry has grown, and what it is at present. Allow me in doing this to rely partly on personal observations.

When, as a student of the Bonn University, I studied chemistry first, about thirty years ago, under the guidance of one of the most famous men, Kekulé, chemical science had, according to our master, come to a dead point.

The existence of atoms, though an indirect chemical conclusion, seemed to have been well established, corroborated as it was by the conception of molecules—a conception which rested merely on physical grounds. The details about the mutual relation in which these atoms stood in the molecule either were already known, or in the case of complicated or new compounds a knowledge of them was but a question of time. Thus H_3COH was used to represent the mutual relations of the atoms in the molecule of a simple compound, methyl alcohol; that is to say, it was known that three atoms of hydrogen are held in some unknown way by the atom of carbon, the fourth hydrogen atom is held by the atom of oxygen, and this in turn again by the carbon atom. Yet all such formulas were merely schemes in the mind, or diagrams on paper, and chemistry was looking out for a kind of Newton who might tell us the laws which hold together these atoms in their constellations, the molecules.

You know as well as I that up to the present time this Newton has never come. Yet, only a few years after Kekulé's disappointing prophecy (which, by-the-by, a teacher should never express before his pupils) stereochemistry awoke, and is now a fully developed and well-founded branch of chemistry. By stereochemistry so much at least was attained that, admitting the existence of atoms, we now know to a large extent, not only the mutual *relations*, but also the mutual *positions*, which these atoms occupy in the molecule. H_3COH becomes



That is, the three atoms of hydrogen and the atom of oxygen were found to be arranged in space around the carbon atom in such a way as to occupy the four corners of a tetrahedron, in the center of which the carbon atom lies.

But there we stood, and still stand, since more than twenty-five years, still ignorant of the laws to which their relative position is subordinated, though a recent attempt seems to me hopeful.

Nevertheless, research went on in a way which had very little to do with that architecture constructed by the mind whose building stones are atoms. So, fifteen years after Kekulé's discouraging prophecy, a second child of hope awoke, and this was physical chemistry. It did not appear at once—a scientific branch hardly ever does—it developed as a plant unseen in the shadow, till it felt the sun, and then grew up to be a giant tree.

Some, as Duhem, even say that physical chemistry is a third fundamental science, entitled to be placed between physics and chemistry. Others, like Winkler and Ladenburg, say that, to begin with, we might allow it a prominent place in chemistry and substitute for the division into the two branches, organic and inorganic, a division into three. It will be of interest to add that the University of Göttingen has recently organized the chemical department on this principle. But, apart from all principle of division, which in the end is always arbitrary, because our whole science, like nature, which it reflects, is only one thing, though rather large, we ask: What has physical chemistry achieved?

There are two ways along which a reply to such a question can be given. I might trace in outline the general conclusions, and might speak to you of the laws of chemical change, of reaction velocity, of electro-chemical processes, but I should not be able to do much without the use of a rather complicated formula, which the character of this introduction excludes.

The second way is of a special nature, and I will venture on it, to trace on what lines physical chemistry wrought out its conclusions and what success it met with. The particulars will apply to one of the best known and farthest reaching achievements, to the investigations on osmotic pressure.

Let me begin with that particular attraction for water which we find in some substances very familiar to us, say in ordinary burnt lime. If the lime is kept in a well-filled flask or bottle, which is not hermetically sealed, water from the surrounding air will be attracted by the lime. This will augment the volume of the lime, and the flask or bottle will eventually give away; a tremendous force is thus developed, too large, perhaps, to be exactly measured.

But, on a smaller scale, we may follow up quantitatively the analogous process with sugar, for instance, in a dilute solution, say a 1-per-cent. solution. This will attract water also, as may be shown by filling with the solution a flask, porous, but permeable for water only, and by placing this flask, when well sealed, in water. Then water will enter it till, if the flask holds, a pressure of two-thirds of an atmosphere is attained, as was measured by Pfeffer.

We may generalize and say every solution has the tendency to diffuse into the solvent as if it were attracted by the solvent, and this tendency will produce a pressure if the diffusion is prevented by a membrane. This pressure, for more than a century studied as osmotic pressure, has a well-defined amount; it was known to vary with concentration, with temperature, and with the nature of the substance dissolved, etc., and this was all we knew about it until the way in which physical chemistry worked was applied to it. The result was so transparent that every student may now calculate readily for any dilute solution what its osmotic pressure is; for all may be summed up in this one expression:

$$P = 0.08\ CT,$$

with P, the osmotic pressure in atmospheres, T, the absolute temperatures, C, the concentration or number of gram molecules of dissolved substance in one liter of the solution. The above value of the pressure for a 1-per-cent. sugar solution is, at once, got at by this formula. Let me only insist on the different way in which physical chemistry works as compared with stereochemistry. Physical chemistry does not seek the solution of problems by trying to reveal the constitution of matter, but it works out between measurable things relations to which the calculus may be applied.

This is not all. Looking upon the tremendous work which atomic chemistry has achieved, one must acknowledge that in research relatively little up to the present has proved of value as to what most interests us, the problem of life. Quite the opposite can be maintained with the lines followed up in physical chemistry; and even ten years ago, I used an occasion like this at Utrecht to point out the large part which this osmotic pressure, the laws of which physical chemistry revealed, plays in physiology.

I could indicate the result of many a physiological investigation, pointing to the fact that osmotic pressure is a fundamental factor in the most different vital functions in plant and animal existence. According to de Vries, it regulates the growth of the

plant; according to Daudres it regulates the functions of the blood; according to Mussart it regulates some functions of the human eye as well as the life of the most deadly infectious poisons, like the typhus bacilli.

Since then literature on the same subject has appeared which might fill a new and most interesting volume, in which the most startling fact up to the present would be the fact realized here by that splendid discovery of Professor Loeb, that the act of fertilization in lower organisms, as sea urchins, may be substituted by a given increase in the osmotic pressure of the surrounding medium.

And I may well quote in conclusion his summary that: "At no time since the period immediately following the discovery of the law of conservation of energy has the outlook for the progress of physiology appeared brighter than at present, this largely being due to the application of physical chemistry to the problems of life."

J. H. VAN'T HOFF.

PSYCHOLOGY AND THE MEDICAL SCHOOL.

IT requires only a minimum amount of consideration for a person thoughtful of the matter to recognize that in the most essential meaning of the proposition, psychology is the most fundamental of all the sciences: psychology discusses the mental processes whereby all perceptible nature is perceived. As long as men continually and of necessity study each other, subject and object alike in modes of consciousness, that body of related facts and principles concerning mind will remain basal, and, consciously or unconsciously, universal. Chemistry, for example, treating of the composition of matter, arrives at its analyses only through mental processes which it is the business of psychology to explain and to facilitate. Astronomy tells us of the planets and the stars, but the astronomer who is consciously or unconsciously nothing of a psychologist may readily deceive not alone himself, but the scientific public, as has happened more than once. To the psychologist no longer 'seeing is believing,' as the ancient adage runs, for the nature of man unfolds itself apace and shows fold within fold undreamed.

Yet on other grounds than these, which are theoretical and philosophic, lies the interest of the science of psychology to all who have the opportunity to intelligently learn its principles—men and women value it and usually become more or less absorbed in it because it describes themselves, and, ever more successfully, attempts to explain what is and must ever be the most regarded of subjects to every agent, namely himself, as individual and as social unit. The biologic egotism implanted deep in every soul sees to it inevitably that all one's life, whatever the social status or the life-pursuit, that soul shall study continually itself, with however apparent indirectness or however elaborate the social system of real or hypocritical altruism may be. Indeed, altruism has nothing to do with the deeper aspects of the interest in question, this interest being beneath all altruism, in the organic mechanism. The degenerate criminal and the flower of ethical manhood play alike on the same fragile instrument, one miserably and the other with far better harmony; this instrument is consciousness and the changes that it manifests are constant in one only thing—it is I, I, I, the type, the sum. It is chiefly on this account that psychology is an interesting science.

But besides being the basal and an eminently interesting science, psychology is a sound science, 'new' but soundly scientific, a thoroughly self-reliant and deep-set department of systematized human knowledge. In substance older than Thales, known as methodical since Aristotle, yet