THE GRADUATE STUDENT AND COOPERATIVE RESEARCH

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The modern graduate student in chemistry in our universities is not generally a boy whose family is heavily endowed with riches. More than nine times out of ten it is necessary for the graduate student to earn his own living by doing work of some type while attending the university.

At the present time the situation is met by permitting the graduate student to act as a teaching assistant in freshman chemistry courses. This has been the subject of much pedagogical argument and the general impression is that our graduate students are not skilled teachers and that the freshman student is apt to suffer. On the other hand, it is almost impossible to get full-time instructors who would be more satisfactory and who could afford to accept a position where the salary is so extremely low. In the last analysis in our large universities if we removed these teaching assistantships we would lose from one-half to ninety percent of our graduate students. This, of course, would be a catastrophe.

It is a natural desire on the part of the chemistry departments of the various universities to see an increase in the number of graduate students in their departments. In the last few years there has been a steady increase in most of these departments due to the fact that there has been a steady increase in freshmen and a resulting increase in the number of teaching assistantships offered. At the present moment we seem to have arrived at a saturation point.

In the meantime our great industrial concerns have suddenly discovered that a research man who has a Ph.D. is considerably more valuable at least in the first few years in their research organizations than the young man who has only his bachelor's degree. The young man with a Ph.D. has been broken in by the instructing staff so that when he starts in work in an industry there is very little change from his academic life. The result of this discovery on the part of our great industries is quite obvious. We now have a tremendous demand for graduates who have Ph.D. degrees. A superficial survey of the situation would indicate the demand is about five times the supply. In other words, it becomes necessary for us to increase our graduate school in chemistry to a point where we will produce five times as many Ph.D's per year as we have in the past. When we have developed to that point, unquestionably the demand will still exceed the supply.

An interesting example of the acuteness of the situation is shown in the salaries offered these young men who have just obtained their doctor's degree. Some years ago the salary offered was $2,000 to $2,400. Last year it was $3,000 to $3,300. This year it is $3,300 to $3,600 and next year it will probably be even higher. This does not take into account men who are especially trained in subjects that are of extreme interest to certain industries. These men are being offered today from $4,000 to $5,000 even though they have had no real practical experience in the industry.

It is quite evident that we cannot meet the situation by putting on more teaching assistantships. Perhaps the most desirable way of increasing our graduate school would be for the university itself to increase its budget and offer research fellowships with a financial stipend equivalent to those of our modern teaching fellowships. This, however, is a rather difficult thing to do because it involves the entire university and not the individual department. If $100,000 were spent every year to "buy" graduate students for the chemistry department, there might be some criticism on the part of the various other departments of the university. On the other hand, it would of course be financially impossible to spend an equal sum on all the departments. Desirable though the plan may be, a practical solution to the problem along these lines is not easily discerned at the present time.

There remains one source of finances that has not been thoroughly appreciated by all the universities, that is the industries. A great many of our large industries are now vitally interested in fostering certain fundamental investigations in educational institutions. The research and development departments of our industries have their hands full in developing applications of science to their particular industry. They have practically no time for purely scientific investigations. On the other hand, if they were able to obtain fundamental data that are not in the literature at the moment, they could materially speed up their own work. It is this collection of fundamental data and the general investigation of fundamental phenomena that our industries are only too glad to foster in outside institutions.

At the University of Illinois the chemistry department has a number of cooperative investigations in progress at the present time. Many thousands of dollars have been spent by the industries on these investigations. So far the results seem to justify this expenditure both from the standpoint of the industry and the university.

These investigations at the University of Illinois are mostly in the hands of professional full-time research men, who already have their Ph.D. degrees and several years experience as research men in industry. Though they are young men they already have an enviable reputation among their colleagues. During the progress of their work it is quite possible that they will become internationally as well as nationally known.

It is quite evident that the industry which is willing to pay for the hiring of such men is also willing to pay for the hiring of several graduate students to help along these fundamental investigations. These graduate students would work directly under a professional research man. It is believed that this arrangement would be satisfactory to all concerned. The graduate student would have better instruction in research than he could have under any other arrangement. The chemistry department would be permitted to increase its graduate school and the ultimate number would be limitless. The industry for a small additional sum would increase the amount of work done in a definite length of time and therefore hasten the solution of their own particular problems. In brief, the utilization of money from the industries on fundamental industrial and scientific investigations seems to be the answer to the problem of how we shall be able to increase our graduate schools.

In order to give a clearer picture of these fundamental investigations which are operated as cooperative projects, there is given below a brief statement of a few of these projects at the University of Illinois.

Some years ago when boiler explosions were more or less prevalent it was noticed that in certain cases a peculiar intercrystalline crack appeared in the boiler plate. This subject has been investigated as a cooperative project of the Public Utilities and the cause of this cracking has been discovered. After the cause had been discovered it was a relatively simple matter to produce a satisfactory remedy. Recently this investigation has been changed to a study of the equilibria conditions involved in boiler water up to the critical point of steam. This phase-rule study of solubilities and the effect of organic matter on these equilibria will mean a great deal for the satisfactory operation of our power plants. It should be possible, after we have obtained all of the important data, to suggest a mode of operation for any particular boiler, or any particular boiler water, that would approach the ideal; for example, there should be no trouble due to corrosion, scaling, embrittlement, or foaming. It can be easily seen that a great many doctors' theses will have to be written before this investigation is finished.

The manufacture of water ice on a large scale in this country has been highly developed from a mechanical standpoint. Chemical engineering features, such as improvement of heat transfer, have also been thoroughly studied. The chemical processes, or rather the effect of various chemical compounds in the water on the growth of ice crystals, have received scant attention. The fundamental principles involved in water treatment have been applied, but no special scientific work has been done in order to improve water as a raw material in ice manufacture. At the present time there are probably between five and ten thousand plants in this country which are forced to distill the water in order to make a satisfactory ice. Even with multiple-effect evaporators, distillation is a costly procedure if one compares this operation with ordinary water treatment. We have found at the University of Illinois, after a rather superficial study of the fundamental conditions, that it is quite possible to remove chemical compounds, such as sodium carbonate, by chemical treatment without resorting to distillation. The inorganic chemical reactions studied, though not new, have received very little attention in the past. It will be necessary, however, to go much deeper in order to remedy the situation for all types of water in the United States. It will be necessary to find out exactly the effect on the growth of ice crystals of each and every constituent found in the water. It will also be necessary to study the effect on crystallization by compounds both inorganic and organic which may be added to the water. From a scientific standpoint this is a rather important investigation, and this cooperative project should furnish considerable material for doctors' theses.

The above few examples are representative of the type of cooperative work we have at the University of Illinois in the Industrial Chemistry Division. Some of the other projects we are working on at the present time are the study of the corrosion in the modern power plant, especially corrosion caused by flue gases; the study of the corrosion which occurs in gas-fired boilers used for heating homes; the determination of specific heats of gases at very high pressures and high temperatures; the conductivity of carbonic acid solutions under high pressure and high temperature; a fundamental study of the reactions involved in the oxidation of various organic compounds, for example, hydrocarbons; the study of gas reactions under high pressures and high temperatures; and the study of the partial oxidation of pure organic compounds both in the liquid and vapor phase, using a catalyst and oxygen as the oxidizing agent.