

CHEMISTRY AT UNIVERSITY LEVEL IN WEST GERMANY

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First let me remind you in a brief historical introduction that Justus von Liebig while lecturing as a professor of chemistry at the University of Giessen (1821–1852) and subsequently in Munich (from 1852) organized in a remarkably effective way the academic training of students of chemistry in the past century by introducing regular laboratory courses and synchronized lectures. His system served as a model on which the training programmes for chemists at other German universities were shaped. In order to coordinate the work at German universities and to permit students to change universities the 'Verband der Direktoren selbständiger Unterricht-Institute für Chemie an deutschen Universitäten' (Association of directors of independent chemical institutes at German universities)—ADUC—was founded at the beginning of the present century and set up mandatory guidelines for a first and a second examination under the auspices of the Association. Such examinations had to be passed prior to the preparation of a doctor's thesis. By government decree these 'examinations under the auspices of the Association' (Verbandsexamen) were extended in 1938 to include an examination for a Diploma in Chemistry.

For this educational system basic subjects for a student are inorganic, physical and organic chemistry as well as physics, which are all included in the first pre-examination taking place after roughly four or five semesters. This is followed by laboratory courses, lectures and advanced classes which lead up to the final examination, held after another three semesters in inorganic, organic and physical chemistry (frequently also in technical chemistry as a fourth subject at technical institutions). The final step is a 'Diploma thesis', written in the course of one to two semesters, after additional experimental laboratory work by which the candidate is expected to show that he is able to deal with a chemical problem applying scientific methods and to present his thoughts in an adequate way. A student should take about ten semesters or five years to graduate as a 'Diplom-Chemist', but frequently six years or more are required. One of the problems is to reduce this time to a maximum of ten semesters. Only a small percentage of students finished their studies with the diploma in chemistry in the past. As a rule, students prefer to write a doctor's thesis on a higher scientific topic under the direction of a professor of chemistry. An average of two years is required for this work. Hence, to reach the doctor's degree the student generally needs seven to eight years of university studies.

At the end of the 1939–45 war the chemical institutes of German universities and technical academies of university standing were found to be

either destroyed or obsolete. Prior to and during the National Socialist régime virtually nothing had been done to modernize chemical studies. For about fifteen or twenty years there had been no change in the situation so that around 1948 little more than a restoration could be realized. The erection of modern chemical institutes accommodating a large number of students of chemistry did not take place until during the last decade. It was then that discussions began on whether chemical studies should be streamlined and condensed and whether the programme should be adapted to modern standards, and to the development of new important areas of chemistry (such as theoretical chemistry, macromolecular chemistry, biochemistry, electrochemistry, etc.).

A new 'skeleton regulation for the conduct of examinations for a diploma in chemistry' was issued on 1 April 1966 by the 'Westdeutsche Rektorenkonferenz' (West German Conference of annually elected presidents of universities) together with the Permanent Conference of State Ministers of Culture. This skeleton regulation is not yet completely satisfactory; it ought to be adapted to the development of modern training programmes.

At about the same time the 'Wissenschaftsrat' (Council of Scientific Advisers) constituted by the Government of the 'Bundesrepublik Deutschland' worked out recommendations for a reform of studies at universities. In a publication by the 'Wissenschaftsrat' of May 1966 a model for chemical studies at university level was described. An attempt is made in this publication to view the scientific training of students and to take the first steps toward a reform of studying by concentrating on a few specific areas suitable in terms of subject and method.

Two institutions—Ministry of Culture and Council of Scientific Advisers—issue rules and recommendations for the main steps of chemical studies so that the faculties for chemistry at the different universities are able to determine regulations for diploma examinations and the doctor degrees according to different local conditions.

For the *basic studies* the subjects of inorganic, organic and physical chemistry as well as physics and some knowledge of mathematics are obligatory. These studies end with the pre-examination for the diploma. The period between this pre-examination and the final examination is limited to eighteen months and is a close and well balanced study of the three basic areas referred to above plus a fourth subject. Special programmes on theoretical chemistry and physical chemistry are under discussion.

Advanced studies focus on one of the basic subjects or on a special aspect of chemistry. Students then take their doctor's degree. These studies require about two to three years.

There are plans to arrange *contact studies* for the advanced training of chemists already in employment. Courses of advanced studies at universities are offered in order to bring up to date their scientific knowledge.

Students themselves have shown considerable initiative to bring about a reform of studies of chemistry through the 'Fachverband Chemie im Verband deutscher Studentenschaften' (chemical division within the German national organization of students). A special guide issued by this organization provides information on university studies of chemistry from the point of view of the students.

The above-mentioned ADUC, under the guidance of a group of professors of chemistry, have discussed proposals for modern study programmes. They are in constant touch with the students' 'Fachverband Chemie', the 'Gesellschaft Deutscher Chemiker' (Association of German Chemists), the 'Deutsche Bunsen-Gesellschaft' (German Bunsen Society), 'DECHEMA' (Deutsche Gesellschaft für chemisches Apparatewesen—German Association for Chemical Equipment), the 'Verband der Chemischen Industrie' (Association of Chemical Manufacturers) and also with the expert committees of the Permanent Conference of State Ministers of Culture in West Germany.

The output of students of chemistry has to be compared with a rough estimate of the needs for graduate chemists. From 1950 to 1967 the number of freshmen in chemistry was between 1200 and 1500 each year. This contrasts with about 800 to 1000 chemists leaving the university with a diploma or a doctor's degree. The demand for chemists could not always be met to the extent desired. In 1968, the number of chemistry students entering universities doubled and from the data so far available for 1969 it appears that it will settle down at that higher level of approximately 3000. To cope with this increased number of students new and bigger chemical institutes will have to be built, more workplaces will have to be provided, studies will have to be streamlined, shortened and better adapted to the requirements of the sociological situation. Hence, it is another of our most important problems to find the adequate balance between the increased number of first semester students, the real capacity of universities and institutes and the future needs for graduate chemists.

Some statistics are given in *Table 1* on the type of work chemists undertake in the various branches of industry, the number of doctor's degrees taken during the last few years and on how they are divided among the different chemical subjects.

Table 1. Distribution of doctor's degrees according to basic subjects and related employment in the industry

<i>Basic subject</i>	1964	1965	1966	1967	<i>Distribution in industrial employment in 1967</i>
	%	%	%	%	%
Inorg. chemistry	18.6	19.0	20.7	18.8	11.2
Org. chemistry	49.8	50.8	47.1	57.4	42.1
Physical- and electro-chemistry	11.9	10.7	11.6	8.3	5.3
Analyt. chemistry	3.4	0.9	2.4	1.4	4.1
Macromolecular chemistry	3.4	4.9	2.8	2.8	10.8
Pharm. chemistry	2.9	2.5	3.1	2.8	4.4
Biochemistry	2.9	3.3	2.4	2.8	5.3
Physiol. chemistry	0.8	1.6	1.0	0.7	0.9
Technol. chemistry	4.2	4.7	6.1	3.4	6.7
Other	1.9	1.6	2.8	1.6	9.2

Ideas and problems requiring attention and discussion are:

- (a) to streamline training in terms of time and concentration on fundamentals and to introduce more thoughts in the sense of 'general chemistry' during the first year of chemical education;

- (b) to investigate the part television or films and programmed systems of learning may play;
- (c) to develop a system of lectures, laboratory courses and supervision allowing the student to initiate his activity in subjects of special interest to him in the different areas of chemistry;
- (d) to provide for better personnel and financial support; and
- (e) to devise better forecasting and estimation of the demand for chemists with different education and research backgrounds.

DISCUSSION

R. S. Nyholm (*University College, London*)—In making the following deliberately provocative comment on Professor Heyns's paper I anticipate in part the discussion on research training, but I feel that we should not miss the opportunity of commenting on the very interesting figures he has presented. He mentioned that 57 per cent of students in 1967 obtained doctorates in organic chemistry but only 42 per cent work in this field; that 19 per cent obtained doctorates in inorganic chemistry but only 11 per cent work in this field; that only 2.8 per cent obtained their doctorates in macromolecular chemistry, whereas 10.8 per cent are used in industry in this area. But is this as serious as it appears? Perhaps the future of polymer chemistry lies more in the application of new methods of synthetic organic chemistry and the use of coordination chemistry than in the refinement of current techniques of polymerization. In short, does industry want us to train chemists in what industry is doing now or should we train them so that they can bring about the changes and new methods which will be used in five to ten years time?

H. Zollinger (*ETH—Zürich*)—Any comparison of major subjects of chemists graduating at universities and subjects of employment in industry as given in *Table 1* presented by Professor Heyns is dangerous and causes misunderstandings. In addition to the arguments against such a comparison given by Professor Nyholm it should be mentioned that some subjects like inorganic and physical chemistry have a higher *educational* importance than indicated by the percentages in industrial employment.

Fortunately some industrial managers who are responsible for the recruitment of young chemists realize that a chemist, who brings a sound knowledge and experience in a specific subject from university, may serve his firm very well in another subject.

The School of Chemistry of the ETH—Zürich decided recently to appoint only Professors of Chemistry and to give up designations like Professor of *Organic Chemistry*. Although this may be called a formality, it is a symbol of our attitude for coordination and amalgamation of all branches of chemistry.

J. F. Bunnett (*University of California, Santa Cruz*)—Most chemical educators agree that education should emphasize principles and that descriptive material should be brought in only to sketch the general setting in which the principles operate, or to provide illustrative examples, or to hold student interest. However, agreement is lacking as to what principles to teach,

or perhaps more important, what aspects of the general structure of chemistry are important enough to justify inclusion. Some research-active teachers have an attitude that only those principles and descriptive material which are related to their research area, or to other areas which, in their estimation, are prestigious are important. On the other hand some teachers assert that an undergraduate curriculum should provide instruction in principles and descriptive material covering the length and breadth of chemistry, in order to prepare the student for all fields of research, and for chemical applications in important areas which are no longer fashionable in research (such as volumetric analysis or the physical properties of solutions).

Predominance of the latter point of view sometimes results in rigid curricula and nurtures teachers who are unaware of major advances in research. On the other hand, the abandonment of material not directly related to currently fashionable research produces chemists of narrow interests.

N. N. Greenwood (*University of Newcastle upon Tyne*)—I would like to comment on Dr Bunnett's contribution. I believe that a real problem is created if curricula are dominated entirely by principles and if facts are only brought in to add flesh to the theoretical skeleton. First, facts do not always agree with current theories or they may not yet have been absorbed into a reasonable set of principles. If we ignore these recalcitrant facts in our teaching we may well give a false impression of the state of our understanding and may jeopardize future advances.

Secondly, the danger of elevating principles above facts is that, whereas theories change frequently, the facts do so less frequently, though their number is continually increasing. Thus, if one reads papers written, say, at the turn of the century, the rationale for the work now seems very dated and the theoretical interpretation almost valueless, though the facts will be substantially unchanged and may have influenced subsequent theories.

This is far from suggesting that our courses should comprise masses of unrelated facts. Clearly we must give a coherence to chemical knowledge, but we must also guard against giving the false impression that all of chemistry is currently understood. What is important in our teaching is that theories should continually be confronted with facts so that our students appreciate the relation between the two. Neither the principles nor the facts in isolation form the basis for a stimulating, significant, and open-ended presentation of chemistry as a living subject. Facts are the vocabulary of chemistry and we cannot talk chemistry sensibly without them.

W. H. Eberhardt (*Georgia Institute of Technology, Atlanta*)—The American Chemical Society has a Committee on Professional Training which has existed since 1936 and which is dedicated to establishing and sustaining the quality of chemical training at the Bachelor's level in the U.S.A. The Committee has three basic activities:

(a) The establishment of a set of Minimum Standards pertaining to faculty, curriculum, facilities and environment and the approval of schools on the basis of these standards. The Committee also monitors on a three year cycle changes in the nature of the school and, if need be, removes a school from the list of approved schools.

(b) The accumulation and publication of data relative to training of chemists. Annually, reports are presented on the number of graduates from approved schools. Biennially, the Directory of Graduate Research provides a profile of faculty and research in doctorate-granting institutions in the U.S.A. and Canada.

(c) Generation and publication of occasional documents providing advice. Two of the most notable documents are a pamphlet, *Preparing for Graduate Work in Chemistry*, directed towards the student, and an article in *Chemical and Engineering News*, **42**, 76 (1964), concerning 'Doctoral education in chemistry', directed to departments contemplating doctoral programmes.

The great value of the Minimum Standards and the approval programme comes from the stature of the American Chemical Society and the support given to the school in obtaining faculty and resources needed to meet these Standards. The most significant criticisms of the programme are directed against its conservatism. Although the Committee has tried to define the content of a chemistry programme along topical lines, its curricular standards are still phrased in classical terms, e.g. physical chemistry, organic, etc.

The Committee is both interested in and sensitive to curricular experiments but slow in adopting or recommending major changes since the implications of such recommendations are great and may be inappropriate to apply on a wide scale.