BUILDING A CHEMISTRY DEPARTMENT

I. The Undergraduate Curriculum

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In 1947 the author received an invitation to join the staff of the Illinois Institute of Technology, in order "to build an excellent chemistry department as rapidly as possible." The Institute had under construction a building which had originally been designed for the use of chemistry and biology but which, after some modification, was devoted solely to chemistry. This building and its facilities have been described elsewhere.[1] The present paper discusses the undergraduate curriculum, and subsequent papers will include discussion of the graduate program, educational policies, students and staff, teaching loads, the annual budget required, and the effect of sponsored research upon the educational program.

The philosophy in planning a new undergraduate curriculum was to graduate a man with a bachelor's degree who would be capable of doing research in a modern industrial laboratory without additional formal training. As it is impossible in a four-year curriculum to teach all of the many and various applications of chemistry to industrial practice, it was decided to confine the teaching to fundamentals.

The usual undergraduate curriculum has a minimum of one year each, with laboratory, of general, analytical, organic, and physical chemistry, with a year of college physics, mathematics through the calculus, and one additional course in chemistry. In the opinion of the writer, this is not sufficient chemistry and other science if the student is to terminate at the bachelor's level and go into industry, and the result is that a student who has chosen chemistry as a profession must go to graduate school for further training.

An undergraduate curriculum should give a man sufficient training in chemistry and other science to terminate at the bachelor's level and, at the same time, afford an opportunity for the exceptional student to go on to graduate school and specialize in his chosen branch of chemistry. This means that a properly trained B.S. in chemistry should be able to use the library intelligently, have sufficient knowledge of instruments as applied to chemical laboratory practice that he can use modern instruments with confidence, and above all be able to think for himself. In connection with his junior and senior courses, he should learn enough of the modern techniques of chemistry that he derive some personal satisfaction from his laboratory work in an industrial laboratory and not be just a "pair of hands" to a Ph.D.

At the same time, facility in oral and written communication and some knowledge of economics, history, and the humanities cannot be neglected in any bachelor's program. Unless a student is convinced that training in chemistry terminating at the B.S. level affords an attractive basis for remunerative employment and satisfactory working conditions, he will naturally turn to other fields. This is especially true of the student who, for financial or other reasons, cannot spend the additional time needed in a university to complete the work for the doctor's degree in chemistry.

During the academic year 1947–48 the problem of organizing an undergraduate curriculum was studied from the above point of view. The curriculum adopted at that time has been subject to continued faculty and student review. During the academic year 1951–52, the chemistry department staff conducted a series of discussions which included a review of the entire curriculum and of the content of each chemistry course and less detailed discussions with representatives from other departments in regard to their courses which were included in the chemistry curriculum. The general conclusion was that the curriculum was satisfactory but that certain specific improvements could be made.

In order to obtain the students' reaction to the curriculum, the I. I. T. Chapter of the A. C. S. Student Affiliates was asked to conduct a survey. A questionnaire was mailed out to some 70 students who had received the B.S. in chemistry from I. I. T. during the period 1948 to 1952, asking for a frank opinion of the entire curriculum, and posing the following questions:

(1) In your opinion, has your training enabled you to compete on an equal footing with B.S.'s in chemistry from other institutions in the United States?
(2) If your answer is *No*, please name the institution and what you consider the deficiencies in your program at I. I. T.

In all but one case, the answer to question (1) was *Yes*.

When the answers to the questionnaires had been received from the graduates, the undergraduates in the Student Affiliate group then conducted their own discussions.

As will be evident from the comments discussed

[1] KILPATRICK, M., in "Laboratory Design," H. S. COLEMAN, Editor, Reinhold Publishing Corp., New York, 1951, pp. 275–9.

below, the student and staff recommendations for changes were often in accord. So few changes from the earlier curriculum were made that it is considered unnecessary to itemize both the 1948 and 1953 curricula. The comments should be clear to the reader by reference to the revised curriculum shown in Table 1.

CURRICULUM

Freshman Year. Inorganic qualitative analysis is included in general chemistry (112).

Both staff and students recommended that algebra and trigonometry, which had been given in the first semester, be required for admission; that analytical geometry be given in the first semester, and calculus be started in the second semester. Educationally this has many advantages, but the recommendation was vetoed by the Institute curriculum committee on the grounds that the training in algebra and trigonometry in the Midwest high schools was inadequate.

The students pointed out that the two-semester course in technical drawing was designed for engineers and contained too much detailed work on drawing of "screws, nuts, and bolts," and did not use the metric system. The staff agreed with them that a one-semester course, emphasizing lettering, graphs and graphical representation of data, sketching, working drawings, and blueprint reading, should be substituted. This change has been made.

Sophomore Year. Both quantitative analysis and organic chemistry, taught in the sophomore year so that physical chemistry can precede the work of the senior year, made a heavy load for the sophomore. A one-semester, one-hour experimental course given by the chairman of the department was eliminated in 1950. The recommended change in mathematics would have decreased the load in the fourth semester.

Junior Year. After a thorough, one-semester course in organic qualitative analysis (331), the majors in chemistry spend two months of the spring semester on semimicro analysis for carbon, hydrogen, nitrogen, and organic functional groups, a month on the newer techniques of inorganic analysis, and a month on "chemistry under the microscope."

The students recommended that physical chemistry be a three-semester course with the elimination of electrochemistry in the senior year. This, however,

TABLE 1
Chemistry Curriculum (Revised) for 1953–54

		First semester			
Chem.	111	General Chemistry	4	4	5
Math.	101	Col. Algebra and Trigonometry	5	0	5
Engl.	101	Fundamentals	3	0	3
B.E.	101	Principles of Economics	3	0	3
P. E.	101	Physical Education	2	0	0
		Totals	17	4	16
		Second semester			
Chem.	112	General Chemistry	4	4	5
Math.	102	Anal. Geometry and Trigonometry	5	0	5
Engl.	102	Composition	3	0	3
B. E.	102	Principles of Economics	3	0	3
T. D.	108	Technical Drawing	1	5	2
P. E.	102	Physical Education	2	0	0
		Totals	18	9	18
		Third semester			
Chem.	223	Quantitative Analysis	2	8	4
Chem.	231	Organic Chemistry	3	6	5
Math.	201	Calculus	4	0	4
Phys.	201	General Physics	4	0	3
Phys.	205	Laboratory Physics	0	3	2
		Totals	13	17	18
		Fourth semester			
Chem.	232	Organic Chemistry	3	6	5
Math.	202	Calculus	4	0	4
Phys.	202	General Physics	4	0	3
Phys.	206	Laboratory Physics	0	3	2
P. S.	420	American Constitutional System	3	0	3
		Totals	14	9	17
		Fifth semester			
Chem.	341	Physical Chemistry	3	6	5
Chem.	331	Ident. Organic Compounds	2	8	4
Math.	410	Differential Equations	3	0	3
Germ.	101	Elementary German	3	0	3
Physics Elective			3	0	3
		Totals	14	14	18
		Sixth semester			
Chem.	342	Physical Chemistry	3	6	5
Chem.	323	Semimicro Analysis	2	8	4
Chem.	351	Chemical Literature	2	0	2
Germ.	102	Elementary German	3	0	3
Humanities Elective			3	0	3
		Totals	13	14	17
		Seventh semester			
Chem.	421	Instrumental Analysis	2	8	4
Chem.	411	Chemical Bonding and Structure	3	0	3
or					
Chem.	441	Electrochemistry	3	0	3
Germ.	211	Scientific German	2	0	2
Phys.	405	Quantum Theory of Struct. of Matter	3	0	3
or					
Bi.	441	Theoretical Biochemistry	3	0	3
General Elective			3	0	3
		Totals	13	8	15
		Eighth semester			
Chem.	413	Inorganic Chemistry	2	8	4
or					
Chem.	431	Organic Preparations	2	8	4
Germ.	212	Scientific German	2	0	2
Phys.	406	Quantum Theory of Struct. of Matter	3	0	3
or					
Bi.	442	Biochem. of Vitamins and Hormones	3	0	3
Liberal Studies Elective			3	0	3
General Elective			3	0	3
		Totals	13	8	15

The first number in the three columns gives the hours per week in the classroom, the second the hours per week in the laboratory or drafting room, and the third the semester hours of credit.

TABLE 2
Chemistry Teaching Option

First, second, and third semesters: Same as in basic curriculum.
Fourth semester: Substitute Psych. 201, Introductory Psychology, for P. S. 420, American Constitutional System.

		Fifth semester			
Chem.	341	Physical Chemistry	3	6	5
Chem.	331	Ident. Organic Compounds	2	8	4
Math.	410	Differential Equations	3	0	3
Germ.	101	Elementary German	3	0	3
Educ.	301	Educational Psychology	3	0	3
		Totals	14	14	18
		Seventh semester			
Chem.	421	Instrumental Analysis	2	8	4
Chem.	411	Chemical Bonding and Structure	3	0	3
or					
Chem.	441	Electrochemistry	3	0	3
Germ.	211	Scientific German	2	0	2
Educ.	303	American Public Education	3	0	3
Educ.	317	Methods of High School Teaching	3	0	3
Educ.	310	Psychology of Adolescents	3	0	3
		Totals	16	8	18

		Sixth semester			
Chem.	342	Physical Chemistry	3	6	5
Chem.	323	Semimicro Analysis	2	8	4
Chem.	351	Chemical Literature	2	0	2
Germ.	102	Elementary German	3	0	3
Educ.	315	Secondary Education	3	0	3
		Totals	13	14	17
		Eighth semester			
Chem.	413	Inorganic Chemistry	2	8	4
or					
Chem.	431	Organic Preparations	2	8	4
Germ.	212	Scientific German	2	0	2
Physics Elective			3	0	3
P. S.	420	American Constitutional System	3	0	3
Educ.	408	Practice Teaching	0	10	5
		Totals	10	18	17

is impractical as the chemical and metallurgical engineers must complete physical chemistry by the end of the junior year.

In the opinion of the students, the course in chemical literature (351) should reduce the emphasis on organic chemistry and spend some time on the less thoroughly systematized fields of chemical physics, physical and inorganic chemistry. Many students objected to our one-year experiment of having a staff member from the English department associated with the course, explaining that although they recognized their weakness in written and oral expression, they felt that the English department should give a proper remedial course. Although this idea is basically a good one, to be successful it requires careful coordination and cooperation between the two staff members. A more easily attainable solution was found by using a staff member from the chemistry department who could play both roles, and in addition to improving the written English of the students, covered the literature in the various fields of chemistry.

Senior Year. In the earlier curriculum, inorganic chemistry (413) and organic preparations (431) were offered with the emphasis on laboratory work, to give the students some training in glassblowing and in the techniques required in preparative chemistry. The students suggested that the organic course should be brought up to the same standard as the inorganic, and should include practical distillation with modern equipment, chromatography and extraction, and, in the lectures, greater emphasis on theory. Both staff and students recommended that an additional semester of lectures on inorganic chemistry be added.

To meet these recommendations, a course in chemical bonding and structure (411) was added as an alternative to electrochemistry (441); and inorganic (413) and an improved organic course (431) were offered as alternatives in the eighth semester.

Instrumental analysis (421) is a course in the theory and application of instruments in chemical procedures, with analysis as a secondary objective. The philosophy is to teach that commercial instruments are not push-button machines which must be returned to the manufacturer for adjustment and repair. In addition to the formal experiments, each student is required to undertake a project, which usually begins in the library, is continued in the student machine shop, and is completed in the laboratory. For example, one year two students built and tested a workable magnetic susceptibility apparatus, and in the next year another student improved the apparatus, with the result that our Freund Instrumentation Laboratory now has another instrument for teaching and research. Although some of the experiments use homemade equipment, the student also works with the laboratory's double-beam infrared spectrometer, Beckman DU spectrophotometer, modern X-ray diffraction machine, polarographs, spectrograph, densitometer, and other modern instruments. The laboratory hopes, as funds become available, to acquire a mass spectrometer and a constant-temperature, constant-humidity room. In the meantime, instruction in the use of the mass spectrometer is provided by demonstrations in the well equipped laboratory of the Institute of Gas Technology located on our campus.

The students also suggested courses in report writing, speech, French, statistics, unit operations, radiochemistry, polymerization, and chemical thermodynamics. It was pointed out by the staff that—after all—we are required to limit ourselves to a four-year B.S. program! Unit operations, report writing, public speaking, and French are available as undergraduate electives; and statistics, chemical thermodynamics, radiochemistry, physical chemistry of high polymers, and a course on the colloidal state are available as graduate courses, and may be taken as electives by specially qualified seniors.

One obvious criticism of the curriculum is the paucity of free electives. Experience has shown us that although students might select suitable courses during the preregistration counseling period, it often happened that these courses were not available because of low registration or scheduling difficulties at the time of registration. The result was that courses were chosen on the basis of availability rather than suitability. To ensure that certain suitable courses would be available, alternative choices were provided instead of electives. The curriculum outlined in Table 1 is the minimum requirement and good students are encouraged to take additional courses during their senior year.

OPTIONS

The basic curriculum and the options outlined below meet the requirements of the American Chemical Society Committee on Professional Training.

Research Option. Only students of exceptional ability are permitted to enroll for this option. Permission is granted upon a written request to the chairman of the department and subsequent approval by the chemistry staff.

The research option is the basic curriculum in which eight semester hours of senior research (491) are substituted for the six semester hours of general electives in the seventh and eighth semesters and the project part of instrumental analysis (421). Senior research is also offered every summer.

Management Option. The management option is the basic curriculum in which 15 hours of approved business and economics courses are substituted for the general electives, and Physics 405–406 or Biology 441–442 in the seventh and eighth semesters.

Teaching Option. The teaching option involves the substitution of 24 hours of approved education and psychology courses in the basic curriculum as noted in Table 2. This program meets the present minimum requirements for education courses in Cook County and the State of Illinois.

The basic curriculum amounts to 134 semester hours, with 59 taken in the chemistry department and a possible six of biochemistry in the biology department. The research option has 136 semester hours, with 67 in chemistry; the management option, 134 with 59 in chemistry; and the teaching option, 139 with 59 in chemistry.

The chemistry department staff is of the opinion that this curriculum provides training for a good chemist at the B.S. level, one who will be able to compete with any in the country. Evidence is already being provided by the approximately 100 graduates of the department since 1947, 30 per cent of whom have gone to graduate school at other institutions. Five have now received the Ph.D. degree, two are instructors in university chemistry departments; one fought off the coast of Korea and another did a tour of duty in the Chemical Corps before going on to graduate school. The others can be found in the laboratories of the Government and in industry in various capacities. Reports from professors in the other graduate schools are more than favorable, and in so far as we have been able to determine and compare, the chemistry students from I. I. T. show clearly the results of better-than-average training in the techniques of the laboratory.

The aim of the department is to turn out a quality product. Not all are from the same mold and there will be great differences, but if you have a sample we would like to hear about the defects as well as the good qualities so that we may improve the product. The product will depend greatly upon the starting material, and we are interested in receiving more and better material for processing.