ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. LIV/LV, 1 SECTIO AA 1999/2000

Chemistry curriculum for the next century

E. Matijević
Victor K. LaMer Professor of Colloid and Surface Science
Department of Chemistry and Center for Advanced Materials Processing, Clarkson University, Potsdam, New York 13699-5814, USA

1. INTRODUCTION

Presently we are witnessing an unparallel revolution in science and technology, especially in areas of communications and medicine; the changes are indeed so fast that it is often difficult to keep up with the new developments. Only few would doubt that chemistry as a discipline has been the major factor in this meteoric progress of our civilization. In his Priestly Medal Address (which is the highest award of the American Chemical Society) the 1999 recipient Professor Ronald Breslow said the following: "Perhaps my most unusual consulting arrangement was as a member of the scientific advising board of General Motors, the largest US car manufacturer. I was amazed to see how much chemistry is involved in the automobile manufacturing – chemists were the largest identifiable scientific group in the research laboratories of GM" (*Chemical & Engineering News*, March 22, 1999).

Yet, in spite of the reality, the interest in this field of science has been declining in many parts of the world, with decreasing enrollments in chemistry at universities on undergraduate and graduate levels. Obviously, it is necessary to seek reasons why the young generations show an adverse or at least indifferent attitude towards our profession.

In part, this response is due to the impression, often promoted by the media, that everything associated with chemicals is poisonous to people or to the environment, causing disease and pollution. Interestingly, the most ardent followers of such erroneous beliefs are frequently the greatest users of the products made by chemists. They wear drip-dry shirts made of synthetic fibers, eat processed food on plastic plates, with plastic utensils, etc. Even the term drug has the connotation of society's evils (which it can be). However, the new medications (drugs), developed by chemists in pharmaceutical industry, have been greatly responsible for increasing the average life-span in most developed countries from about forty-five to seventy-five years in the last century alone!

Obviously our professionals have not been successful, or eager enough, to rectify the misunderstandings on the part of the general public and to properly present the true functions of chemistry, which would attract young people to seek careers in this "central science".

2. EDUCATION

There is another aspect of equal significance in discussing the state of chemistry as a profession, and that is the educational. It would appear that instruction on the subject has not kept pace with the progress in this field of human endeavor. In looking at textbooks of chemistry, it is easily recognized that in the majority of cases the approach is traditional and – boring. More importantly, often only lip-service is given to the relationships of chemistry to other disciplines, such as materials, medicine, computers, etc. Indeed, not enough effort is invested in order to demonstrate the benefits of chemical compounds and processes to our well-being. Presently, it is very popular to talk and write about the importance of the interdisciplinary aspects of research and education. In reality little is done to truly implement such ideas in the teaching programs.

Traditionally, the organizations of chemistry curricula and faculty have been divided into analytical, inorganic, physical, organic chemistry and, occasionally, biochemistry. Lectures and laboratory courses have been scheduled along these "specialties" as well. This system was initiated over a century ago, when it made sense in view of the state of our discipline. In the past such classifications served a good purpose and offered to chemistry education community a sense of consistency and stability, since most of the scientific developments could be categorized into the listed areas. The fact is that these divisions have become obsolete, although not so generally recognized. The latter is easily understood, because it is difficult to change a system that seemed adequate for such a long time. A quotation in an article published in the *Chemical & Engineering News* of March 9, 1998, reads, "trying to bring change to an institution of higher learning is like moving a graveyard – the residents don't help you much". It is necessary to do better!

3. A NEW APPROACH

In view of the fact that at present research and development activities do not require clear boundaries among traditional divisions of chemistry, it makes little sense to offer separate courses in these areas. Thus, there should be no need to teach separately the syntheses of organic and inorganic compounds. There may be variations in some procedures, but the basic principles behind both organic and inorganic processes are more common than different. For example, let us consider the formation of macromolecules, both organic and inorganic; they are all produced by linking monomers via covalent bonds. Similarly, there is much in common in analytical chemistry of organic and inorganic compounds, since in both instances one uses essentially the same instrumentation.

Equally important is the change in the expectations that is placed on chemistry graduates in the present environment of modern technology, medicine, and other professions. While it is absolutely necessary that chemistry majors have an excellent knowledge of fundamental principles, it is equally important that they should be able to apply these principles in their respective jobs. The technological and medical developments during the last decades have made it necessary to radically change the current chemical education system. For example, thirty years ago a chemist was expected to deal in his professional life with mostly one-phase systems, typically making new molecules to be tested for different applications. In contrast, just as an example, today's chemist – and to an even higher degree the chemist of the future – is expected to handle multi-phase matter with the intriguing possibilities for new preparative methods, and to understand the fundamental phenomena of complex materials. Let us mention the most recent interests in nanocomposites in inorganic/organic polymer structures, thin films, or systems which could not even be categorized within the classical definition of solids or liquids.

4. SCOPE OF THE CHANGE

There are two essential and novel aspects in the proposed chemistry curriculum:

1. *The integration of courses by abandoning the traditional artificial division of classical areas of chemistry. The approach involves a logical sequence of events in chemistry, starting with the preparation of simple and composite materials, followed by a comprehensive use of modern techniques for their characterization, and then study their formation and interaction mechanisms.*
2. *An early emphasis on specific areas of specializations with respect to different fields of applications with opportunities for more intense research at the undergraduate level.*

The proposed specializations are based on the obvious needs in view of technological and medical developments and the strength of the existing faculty.

Some of the possible groupings include:

Fundamental Chemistry (no specific specializations)
Chemistry and Materials Science
Chemistry and Environmental Science
Chemistry and Biological Science
Chemistry and Computer Science
Chemistry and Intellectual Property

The scheme can be expanded to include other directions as the demand and condition of a university would justify.

5. IMPLEMENTATION

The proposed program is based on the integration of lecture courses and closely related laboratory classes, with a carefully planned sequence. For example, during the first two semesters a descriptive course covers the properties and reactions of organic *and* inorganic materials, found in the nature or prepared for various applications. This organic/inorganic course should be combined with simultaneous two semesters of chemical syntheses laboratories, including inorganic, organic, organometallic, and other compounds.

The sophomore year includes an integrated course that covers the chemical and physical properties of organic, inorganic, and composite materials. The laboratories for sophomores deal essentially with the chemical characterization of these materials in a considerably more comprehensive manner than the traditional analytical laboratory, and include modern methods for the evaluation of gases, liquids, and solids in homogeneous and heterogeneous media. Consequently, the traditional analytical chemistry needs to be expanded to cover a much wider scope of techniques. For example, why spend much time on acid/base titrations. Instead, the exercise should involve titration of silica with a base, or alumina with an acid to determine the number and the nature of surface charged sites on these solids. Such results can then be combined with electrokinetic evaluation of the same particles. Or, it would be useful to employ different techniques, including NMR, spectroscopy, amino acid analyzers, etc. to characterize proteins. Thus, there is no need, say, for a course in spectrophotometry (which seems to be quite common); instead, the principles would be incorporated in such integrated studies of the natures of groups of compounds, inorganic and organic!

For this kind of approach a good background in mathematics, physics, and physical chemistry is necessary. While the foundations in the first two areas will be gained in the freshman year, physical chemistry is required during the sophomore year. The latter is essential, since at present time the vast majority of methods for characterizations of materials is based on physical chemical principles.

In the third year, the laboratories need to be focusing on the rates of chemical processes (kinetics) and the thermodynamics, which are applicable in general, while the fundamental principles had been expounded in the sophomore year physical chemistry. In addition juniors will have an option to take elective courses in different areas of chemistry.

The senior year would focus on specialized subjects and research. For an advanced specialization in either Materials Chemistry, Environmental Chemistry, Chemical Biology, or Computational Chemistry, etc, the undergraduate student will have to complete at least six courses from a list of relevant electives.

Such offerings must be designed with the future developments in mind. For example, no course should be simply titled "crystallography" or "crystal growth". Instead, the students should be exposed to problems of producing crystals in microgravity (space shuttle!), macrogravity (large centrifuges), in addition to the usual concepts of crystal science under normal conditions. The so constituted topics would certainly have a greater appeal to students than the traditional way of handling the subjects.

Needless to say, it should be possible to design a curriculum which would add an additional year of specialized courses, allowing the student to complete a program for a Master of Science degree, where such degree is offered.

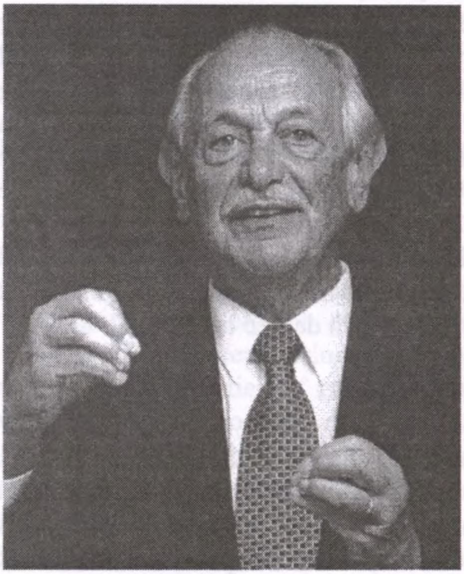
6. TEAM TEACHING

Considering the integrated nature of the new courses in the proposed system, and the expertise of faculty in a given chemistry department, a substantial number of courses will have to be team-taught. When managed properly, this approach would provide an additional venue for different specialists to interact with each other and to soften the boundaries between traditional disciplinary lines. Furthermore, it may be advantageous to call upon faculty members of other departments for participation in teaching specialized courses, which may also lead to their collaboration in research. As an example, one may consider a course in water purification (environmental science direction), in which the subject of flocculation is taught by a (colloid) chemist, environmental engineer, and chemical engineer. It is obvious that students would be exposed to entirely different aspects of the same practical yet essential application.

7. CONCLUDING REMARKS

Needless to say, there is a large number of possible variations to a revised chemistry curriculum, which could be designed to modernize the education in our discipline. The proposed scheme is one such suggestion, the purpose of which is to trigger the interest in order to radically change the system, which served its purpose well, but is badly outdated considering the progress in the science and technology. It is the chemistry faculty that should take the lead in such activities, rather than to expect various administrators to show the way or impose changes upon us.

CURRICULUM VITAE



Prof. Egon Matijević. Born in 1922 at Otočak in Croatia. In 1944 he received diploma in Chemical Engineering from the Technical Faculty of the University of Zagreb, Croatia. Four years later he received there his Ph. D. degree. Next he completed there his habilitation in 1952.

After leaving the University of Zagreb in 1956, he spent one year as a Research Fellow at Cambridge University, and next moved to Clarkson University in Potsdam, New York. Since 1986 he is a Distinguished University Professor there. As of January 1 he is the holder of the Victor K. LaMer chair in colloid and surface science. So far Professor Matijević has published over 500 papers, and registered 14 patents. He wrote 3 books and was Editor of other 16 books. Having achieved a large international recognition, he was invited to deliver plenary or keynote lectures at more than 50 international conferences, organized in many countries (USA, Canada, France, England, Spain, Italy, Russia, Croatia, Hungary, Belgium, Norway, Germany, Japan, Taiwan, Australia, Puerto Rico, ...). In some of the countries Professor Matijević spent longer time as a Visiting Professor delivering a series of lectures (Switzerland, Finland, Norway, Germany, England, Italy, Sweden, Russia, Japan, Australia, Argentina). His international scientific activities are also reflected by the memberships of various prestigious societes, including:

- Academy of Ceramics (Italy)
- American Association for Crystal Growth
- American Ceramic Society (honorary)
- American Chemical Society
- Croatian Academy of Sciences and Arts (foreign)
- Croatian Chemical Society (Zagreb, Croatia) (Božo Težak Award)
- International Association of Colloid and Interface Scientists
- Kolloid Gesellschaft (Germany) (lifetime honorary)
- Materials Research Society
- Sigma Xi (Clarkson Chapter Award, National Lecturer)
- The Chemical Society of Japan, Division of Colloid Chemistry, (honorary)
- The Materials Research Society of Japan, (honorary)

He served also as a member of Advisory Board of various international journals. (*Croatica Chimica Acta, Chemistry of Materials, Colloid Journal of the Russian Academy of Sciences, Colloids and Surfaces, Langmuir, Colloid and Polymer Science, Journal of Colloid and Interface Science*).

During the period 1983-1989 Professor Matijević served as the President of the International Association of Colloid and Interface Scientists. On the list of the Ph. D. theses supervised by Professor Matijević are 44 names, including Francis I. Mangravite who was the prize winner in 1972 – for the best Ph. D. thesis, selected by the American Water Works Association. Very impressive is the list of the scientists visiting his laboratory. These were 117 collaborators from all continents. That list includes also Polish colleagues, who remember with a great sentiment their long-term visits to his laboratory.

Professor Matijević made also several visits to our Faculty of Chemistry in Lublin, before and after he received the degree of Doctor Honoris Causa of our University in Poland. He received degrees of Doctor Honoris Causa from four Universities:

- 1977, Lehigh University, Bethlelem, Pennsylvania, USA
- 1990, Maria Curie-Skłodowska University, Lublin, Poland
- 1992, Clarkson University, Potsdam , New York, USA
- 1998, University of Zagreb, Zagreb, Croatia

Egon Matijević is the only scientist to receive all three awards of American Chemical Society (The Kendall, Iler, and Langmuir Lectureship). He is also the recipient of the Thomas Graham Prize, the highest recognition by the German Kolloid-Gesellschaft.

Throughout his carrer Professor Matijević has been a devoted teacher. Indeed, he taught the general chemistry course to generations of Clarkson freshman. It is being said that one half of all living Clarkson alumini attended his classes!