CHEMISTRY IN ENGINEERING CURRICULUM

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Abstract: *At DonSTU the courses in chemistry are in the process of continuing restructuring to meet the changing demands to engineering education. The paper outlines the role of chemistry in rapidly developing modern engineering education and necessity of restructuring its courses. Together with other natural sciences, chemistry constitutes the fundamental scientific core of engineering education and helps to develop in students the scientific method. The leading principles in restructuring are more efficient integration with other sciences, an intensive use of mathematical methods and quantitative approach, focus on developing problem-solving abilities, a strong emphasis on environmental aspects, increasing attention to social aspects of chemistry. The paper provides an example of such approach: a consistent algebraic approach to stoichiometric calculations in chemistry.*
Key words: *engineering education, fundamental sciences, chemistry, problem solving.*

Last decades have seen a tangible decline in the role of chemistry in engineering education. For example, at many technical universities in Ukraine the number of class-work hours given to chemistry decreased twice as compared to the beginning of the 1990s. For some engineering specialities, chemistry has been excluded from the curriculum at all.

In part, that may be regarded as just one more symptom of chemophobia so common now for public attitude. A fear of dangerous contamination of food, water and air with chemicals at undetectable levels is widespread among the general population. Here chemistry is often regarded as the villain, producing substances and using processes that damage environment [1]. Many people who have come to dislike chemistry at school or college go to non-scientific professions and become lawyers, journalists, politicians. They make decisions that come back to scorn chemistry and chemical profession.

However, there are also internal reasons why chemistry - this fundamental and interesting discipline - loses many of the very students who need knowledge of it. In teaching ‘the science of substances’ many chemists ardently follow the old tradition of presenting qualitative and verbose rather than concise and quantitative descriptions of chemical laws, phenomena and experimental observations. The tendency to avoid measurements and mathematical treatment may be followed down at least to the alchemists’ times. Some people even think that it is an almost inevitable characteristic of ‘chemical mentality’. No doubt, such style contradicts the approach accepted in other exact sciences. For many it can seem boring in our age of the information revolution.

To survive in the system of engineering education that is now in a period of rapid development and transition, teaching of chemistry at technical universities should be substantially changed and restructured. This paper describes some trends in restructuring chemical courses at Donetsk State Technical University (DonSTU). From our point of view, such modifications are essential to meet the changing demands to engineering education.

Why is chemistry important to an engineering student? No matter what one thinks about chemistry, nobody will deny that it is a very important subject. Chemistry is involved in almost everything in our daily lives from clothes we wear to the air we breathe, and the food we eat. Virtually, everyone needs to know some chemistry.

Nobel laureate (1994) in chemistry George A. Olah writes on the role of chemistry in modern society: «*Chemistry has a major role to play in our lives and the lives of future generations. Not only in exciting fields like the biological and health sciences, where chemistry contributes a great deal to our understanding at the molecular level, but as a core*

science in its own right. Chemistry is often maligned - we are the guys who are fouling the atmosphere, we have the stinky plants, and so on. But we are also the guys who can produce essential materials and compounds that are touching all of our lives»[2].

Specifically, why is chemistry important in engineering education?

The answer to that question is very clear for a chemical engineer for whom chemistry is the professional area. Of course, chemistry, on its own, will always be a key science for chemists. But what can chemistry contribute to the knowledge and competence of a new mechanical or electrical engineer?

From our point of view, the role of chemistry in modern engineering education may be summarised in the following way.

a) As one of natural sciences, chemistry constitutes the scientific core of engineering education. It helps to form in students *the scientific method* as a basic component of engineer's mentality. Our guiding principle is that the desire to develop in engineering students ability to use a scientific method is far more significant than the desire to give them just a body of chemical knowledge - however important the latter is in their professional area. For that, a consistent and thoughtful focus on learning chemistry by reasoning the way to an answer is needed. The aim is to show our students how to develop problem-solving skills by asking the right questions rather than merely applying the right formulas.

b) Chemistry provides a bulk of chemical knowledge, *particular chemical facts* needed in an engineering profession. For example, a mechanical engineer should understand the features of corrosion and the properties of lubricants. A mining engineer should be aware in chemical properties of explosives and, to use them correctly, such chemical notion as the oxygen balance of explosive substance *etc.*

c) Chemistry provides *the basis for material sciences*. The properties and chemical behaviour of constructional materials are of primary interest for civil or mechanical engineers. The chemical properties of silicon are essential for understanding the integrated circuits in computer technology. The equilibrium state and relaxation of electrically, magnetically or optically active centres, that define the properties of functional crystalline materials for use in electronics, are controlled by the very same laws of chemical thermodynamics and kinetics.

d) Chemical thermodynamics and kinetics are basic components of *the theory of technological processes* dealing with the objects that cannot be treated as material points. To design a technological process, the engineer should first to determine whether this process is thermodynamically possible at all under given conditions and then, if it is, to analyse what are possible velocities or rates of the process and how they can be regulated and controlled.

e) Chemistry is one of the most important parts of *environmental sciences and environmental education*. Just as everyone needs to know some chemistry, any engineer must have awareness in environmental sciences. There is a deep concern today about the state of our environment. Current events constantly remind of threats to the environment ranging from individual exposures to hazardous and toxic substances to phenomena on a global scale that may cause catastrophic changes in planet's climate. All such matters involve environmental chemistry for comprehension of the problems and for arriving at solutions to them [1,5,6]. Most of environmental problems can be solved through understanding the chemical processes that cause environmental damage and by knowledge of chemical reactions and processes that are fundamental for preventing environmental pollution, effective use of limited natural resources and utilisation of wastes. Taking into account these reasons, *a continuing environmental education* of engineering students has been introduced at DonSTU [8].

Restructuring chemistry courses. To meet the changing demands to engineering education, the teaching of chemistry should be reformed. Coming next are the principles that we follow to in restructuring the courses in chemistry for engineering students at DonSTU.

a) The aim to gain *a scientific attitude* is achieved by growing experience in studying the whole complex of fundamental sciences. That means *more efficient integration of chemical courses with other exact sciences*. As a philosopher said, "Whoever only understands chemistry, does not even understand this". We emphasise throughout the course that a uniform scientific method can be deployed to solve a whole variety of problems. The best way to understand chemistry is to perceive how a limited number of fundamental scientific laws manifest themselves in the tremendous diversity of chemical facts and phenomena.

b) Related to this is an increased use of *mathematical methods*, graphical presentation, statistical and graphical treatments of experimental data. As an example, the use of standard algebraic approach to stoichiometric calculations in chemistry [5] is given in the following part of the paper.

c) The style of teaching a chemical course is changing to the more *concise and quantitative description* of chemical laws and phenomena. Students should be supplied with the background that allows them to quantitative laboratory work as early in the course as possible.

d) More attention is focused on solving problems and application of chemistry for engineering tasks. An increased accent is made on interrelations between chemistry and other sciences and technical subjects to develop the ability of solving interdisciplinary problems;

e) Special attention is given to social and environmental aspects of chemistry, the role of chemical knowledge in humanistic education. Option courses on the history of chemistry and chemical technology and on scientific methodology and ethics have also been introduced to intensify this aspect of education.

f) Teaching chemistry in English has been provided at English technical department in DonSTU to develop in students communication abilities at international level.

These principles have been realised, in particular, in our recently published manual for engineering students «A course in general chemistry in examples» (in Russian) [5,6].

Role of Mathematics. Mathematics is a universal symbolic language of science and in this role is widely used in such quantitative areas of chemistry as thermodynamics, kinetics, electrochemistry [1,3,4]. Using chemical laws and definitions generally involves algebraic calculation and manipulation, including solution of the relevant equations. An odd exception is stoichiometry. The traditional tendency is to treat basic problems in chemical composition and reaction stoichiometry by means of proportion or factor-label methods [4,7]. Such approach is inconsistent and unnecessary.

For more than ten years we have been proposing to our students to use a consistent algebraic method of solving stoichiometric problems [5]. The method is based on direct application of the fundamental chemical notions of mole and stoichiometric relation as well as logical and uniform algebraic procedures. The similar method has been described also in another work [7].

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