EDUCATION AND GREEN CHEMISTRY

Maria N. Ivantsova, Olga V. Shabunina, Anatoly I. Matern

Federal State Autonomous Educational Institution of Higher Professional Education «Ural Federal University named after the first President of Russia B.N.Yeltsin», Institute of Chemical Technology

620002, Russia, Ekaterinburg, Mira str., 28

Abstract
Chemists, scientists and teachers of the Ural Federal University and chemical institutes of the Ural branch of the Russian Academy of Sciences suggest increasing the level of knowledge in the chemistry for pupils and students. Besides support of youth chemists which are the future of our science and industry is the main aim of our «Green Chemistry» project. One way to achieve this goal was the idea of creation of the charity Fund "Green chemistry". Work in this direction help to increase the interest of youth to chemistry, physics and engineering Sciences.

Key words*: Education, green chemistry, endowment, university, academy of sciences, summer school, chemical tournaments and matches, Olympiads, pupils, students, teachers of chemistry*

The World and Human consist of the substance. The substance is a subject of chemical science. Besides, chemistry is a social science. The scientists of the world use main principles of chemistry to solve different tasks. Modern chemical education insistently addresses to the problems closely connected with the interests, requests, and life values of people. Molecular biology, genetic engineering, biotechnology, and materials science are the fundamental chemical sciences. The progress in medicine and health protection are the challenges of drag and food chemistry. The humanity is waiting for the novel materials possessing the magical properties, new sources of energy storage. Besides, people need new environmentally friendly and safe, resource-and energy-efficient "green" technologies closed to the nature (Lancaster 2010).

Green chemistry or chemistry for sustainable development is known to become of the popular one all over the world. Sustainable development satisfies the needs of the present generation without jeopardizing the ability of future generations to meet their own needs. The crucial role in sustainable development plays the "green chemistry". The "green chemistry" scientific direction was founded in the 90s of the 20th century and has quickly been supported by the chemical society. New schemes of chemical reactions and processes, which were developed at many laboratories around the world, are designed to drastically reduce the environmental impact of chemical production. Conversion from simple waste pollution to the design of new chemical processes, which are able to reduce the environmental influence at all stages from the power generation to recycling, is very important. The maximum safety for humans and the environment is an important criterion in the process of selection of the most appropriate way to the target products with the desired properties. There are twelve principles of green chemistry (Anastas 1998, 2010):

1. Prevention (It is better to prevent waste than to treat or clean up waste after creation.)

2. Atom Economy (Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.)

3. Less Hazardous Chemical Syntheses (Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.)

4. Designing Safer Chemicals (Chemical products should be designed to effect their desired function while minimizing their toxicity.)

5. Safer Solvents and Auxiliaries (The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.)

6. Design for Energy Efficiency (Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.)

7. Use of Renewable Feedstocks (A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.)

8. Reduce Derivatives (Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.)

9. Catalysis (Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.)

10. Design for Degradation (Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.)

11. Real-time analysis for Pollution Prevention (We need to develop analytical techniques to monitor in real time for the formation of hazardous substances.)

12. Inherently Safer Chemistry for Accident Prevention (Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.)

The new generation is certain to determine the future. Science and industry are looking forward to the qualified specialists with the modern mind, who are able to undertake the life tasks. Universities are waiting for the well-trained enrollees. Technical and natural science directions at universities require mostly physics or chemistry as profile subjects. In some cases, programming is in demand. Specific equipment, special material equipment and big complexity in teaching and learning these subjects in schools lead to a significant reduction in the level of training. Thus, the number of applicants who take exams in these subjects is decreased.

As far as the chemistry subject is concerned, it is not required as the final exams at school. It must be taken for admission to universities in the following areas: chemistry and chemical engineering, medicine, building, biotechnology, and others. The chemistry exam is not very popular. Only a pupil chooses chemistry out of ten graduates. In 2013, the unified state Exam in chemistry occupied 7th position of popularity among the graduates. 3.5% of them who passed at that year have chosen exam in chemistry as an additional one. For example, average mark in physics decreased from 55 points in 2013 to 46 points in 2014, in chemistry - from 69 to 56. Chemistry subject requires, of course, considerable effort in organizing and teaching. Especially a lot of problems arise with organization of the laboratory courses. The main purpose is the safety for pupils. Besides, we carry out experiments with some reagents, many of them are required to have permits and admissions. Level material equipment of chemical cabinets is low. The lack of chemical laboratory practice is a significant problem as well. Severe restrictions concerning the use of chemicals in schools allow to carry out only the most simple experiments and laboratory works. "Hours" on this subject are significantly decreased. In secondary schools, the study of chemistry and physics in 10-11 grades is provided with an hour a week. In addition, schools have essential problems with staffing, because of the teaching profession in recent years has significantly reduced in popularity. Quality of training university entrants to chemical departments is steadily reduced.

The methodology S_N^H as a part of green chemistry

Modern trends in organic synthesis are known to be associated with so-called green chemistry, which prompts development of novel atom efficiency and environmentally benign synthetic methods. In this respect, the formation of new C−C bonds has always been a focus of attention as the key element of diverse synthetic methodologies. From a variety of methods that enable the C−C bond linkage of two organic fragments, e.g., two aromatic or heteroaromatic rings, the well-known crosscoupling reactions, especially those that provide direct C−H functionalization, are elegant and advanced synthetic methodologies.

Scientists from different countries, namely Oleg N. Chupakhin (Russia), Mieczysław Makosza (Poland), Henk C. van der Plas (Nederland) and Valery N. Charushin (Russia), are actively developing the methodology of the nucleophilic substitution of hydrogen (S_N^H) (Chupakhin 1994, 2004, 2014; Makosza 2010).

C−H/C−H coupling strategies that correspond to the green chemistry principle of atom economy were placed at the top positions in the "List of More Aspirational Reactions" of major pharmaceutical companies, as the most advanced methodologies, aimed at reducing human impact on the environment.

Besides, this methodology as a part of green chemistry is taught to students of Institute of Chemical Technology.

Endowment Fund

At the beginning of 2012, the endowment fund was founded in the Ural Federal University. The founders of the Fund are persons who embody more than 20-year history of the two largest universities in the Urals, namely (Rectorate 2014):

- Professor Stanislav S. Naboichenko – the president of the University, corresponding member of the Russian Academy of Sciences, the former rector of USTU;
- Professor Vladimir E. Tretyakov – the advisor of the Rector, Corresponding Member of Russian Academy of Sciences, the former rector of USU;
- First vice-rector Anatoly I. Matern and Dmitri V. Bugrov, the former rectors of USTU and USU respectively and lead universities to unite and actively supervise the integration and development of competence of basic and applied areas;
- Viktor A. Koksharov – the current UrFU rector.

Endowment is a very important tool to support the university community, which is in common use in both many international universities and a number of Russian ones for a long time. Fund helps to solve not only strategic issues, but also to invest in support of the talented youth and the infrastructure development. The implementation the mentioned points allows to strengthen the leading position of the Ural Federal University in Russia and in the world. A distinctive feature of the endowment is spending only the fund income.

The purpose of the Fund is the endowment formation, its use and distribution of income from the endowment with purpose of UrFU development in education, science, health, culture, physical culture and sports, arts, and social assistance. Today three target capitals formed in the endowment fund of the University:

- target capital to development of UrFU;
- target capital "Green Chemistry";
- endowment of Higher School of Economics and Management.

Target capital "Green Chemistry"

The decision to establish the endowment was made by fund board in May 28, 2012. The purpose is to develop and to support the chemical education at the university and in the Ural region. The offer was fixed by cooperation agreement between the UrFU and the Ural Branch of the Russian Academy of Sciences on the 13th of July of 2012. Affiliation chemical industry to the project is expected.



Fig.1 Cooperation agreement between the UrFU and the Ural Branch of the Russian Academy of Sciences.

The Fund accumulation of may be used to support chemical education, to hold the youth chemical schools. Implementation of perspective youth projects, including in the field of "green chemistry", the participation of young scientists in symposia, and Russian and international conferences will be supported. There are also other forms of support for talented young chemists.

"Green Chemistry" Project of Chemical Education

The educational and scientific community understands that it an attention should be paid to schools. Schools should be assisted in the development of natural science subjects, attraction of the children, encouragement of their curiosity, and in demonstration of the creative essence, the vital necessity and the prospect of these subjects.

Chemists, scientists and teachers of the Ural Federal University and chemical institutions of the Ural Branch of the Russian Academy of Sciences suggest revealing the importance of chemistry for enrollees and supporting the talented Russian youth, the future of our science and industry. Teachers, researchers, students and graduate students should initiate an interest of the youth in chemistry, physics and engineering sciences and promote the professional choice of the youth. Besides, it is important to help schools and teachers to overcome the difficulties in the development of the natural sciences.

A way to accomplish all of these purposes was an idea of foundation of the "Green Chemistry" charity fund. The initiators and founders were the representatives of the Ural school of organic chemistry, namely Oleg N. Chupahin, Valery N. Charushin, Vladimir L. Rusinov and Anatoly I. Matern. Academician Valery N. Charushin, who is the chairman of the Presidium of UB RAS, gave comments on this initiative: "We have founded the Endowment named "Green Chemistry" to support the talented young people, especially pupils, undergraduate and graduate students carrying out research in the chemistry field. The word "green" has a double sence in this case, meaning not only the "young-green." Nowdays there is a serious trend in the development of chemical science concerned with creating the more rational, possibly direct, atom-economical methods of synthesis, reducing consumption of raw material and energy resources and waste using the available natural solvents - or completely abandoning their application - and using other modern technologies reducing the negative chemical effect on the environment."

The first projects of "Green Chemistry" Fund will include a variety of educational, trial and game activities, the experience of previous years and the new technologies will be used.

In the "Green Chemistry" project we emphasize that we will focus on young people, namely we go to school. We will provide assistance to students, young scientists, teachers and graduate students who are due to this project. At the same time, "Green chemistry" identifies main trends in the industry. We would like to train the children, promoting new technologies, which are comparable with the nature.

Thus, for example, Full-time school of young chemist will continue the work. The tradition of USU and USTU to work with talented students in chemistry and physics will continue as well. Lessons will be held in separate groups for pupils of 8,9,10 classes at the Institute of Natural Sciences, Chemical-Technological Institute, Physical-Technical Institute (PTI) of the Ural Federal University.

The summer school of chemists is supposed to be founded. The summer School for Young Chemists is a short-term intensive training course for secondary school students during the summer vacation period. It will be held at the Organic Chemistry Department and at the Technology of Organic Synthesis Department of the UFU. The chemistry, being one of the most interesting sciences, is going to be demonstrated to the pupils during 3 weeks. Basic parts of the School are lectures, interactive sessions, workshops, quizzes, contests, excursions and own sociological research. Besides, pupils will use the complex scientific equipment. They will be able to receive the first scientific results and discoveries as well.

The main objectives of the summer school are revealing the pupils, possessing the unusual creative mentality and being inclined to the research work, support, and further development of these pupils.

The objectives of the Summer School are:

- development of pupils' interest in creative and research activities;
- involvement in educational research work of talented pupils;
- identification and selection of pupils who are able to do research and additional work with them;
- development of additional forms and methods of work with talented pupils;
- creation a situation of individually based learning by means of the direct communication and collaboration (up to work in a research group) with scientists, teachers, students and pupils;
- a harmonious combination of research and educational work with active rest and recuperation;
- encouragement students to continue research on selected topics during the school year and to present their results at the regional competition of young chemists and other competitions and conferences;
- implementation of the idea of continuing education through training of talented pupils to continue studies in the Ural Federal University.



Fig.2 Development of pupils' interest in creative and research activities.

In addition, Extramural School of Young chemist, which will be aimed at the organization of extramural chemical classes for pupils of Ural regions who cannot an opportunity to visit professional classes during the school year, is supposed to be founded. Material designed for distance training of

students in chemistry, as well as in the main subjects the exam is passed, with the possibility of externship has been designed. Educational content of Ural Federal University in chemistry and other subjects will be available at the request of students (Ural Federal University 2014). Organization of classes of Outreach School for Young Chemists during a vacation based on specialized scientific center of UFU is planned.

Learning Objectives are:

- to enable the pupils who are interested in the subject, to improve their knowledge, to learn the initial ideas of the chemistry and lay the foundations for an appropriate education;
- to teach pupils to the basics of scientific mentality;
- to give rise to self-employment;
- to assist teachers and parents to work with talented children.

Directions of school activities:

1. Development of distance forms of education services, introduction of innovative educational, satellite and information and communication technologies in distance education.

2. Development of distance programs of profile and preprofile training on basic, core and elective courses at school, their testing and introduction of distance learning system based on distance educational technologies.

3. Deepening of content of provided educational services on the subjects of natural science profile.

4. Implementation of quality of preprofile, profile training and other educational services based on distance learning technologies.

5. Expanding of the range of educational services of distance school and development of new types of activity:

- organization of preparatory training courses;
- providing creative and research activity of pupils on the basis of distance learning technologies;
- preparing pupils for regional, district, national and Mendeleev Olympiad on chemistry and other subjects of science cycle;
- providing scientific and methodical work of teachers using distance learning technologies.

6. Upgrading information technology base of school.

7. Preparing teachers in subjects of natural sciences, including subject-tutors and educational support staff (trainers, network administrators, database administrators, etc.) in the field of information and communication technologies with the use of distance learning technologies.

8. Establishing partnerships with the other distance schools.

The practical work for pupils of the specialized classes (9, 10, 11) of chemical and chemical-biological destinations of schools and gymnasiums in Yekaterinburg is being performed on the basis of the various departments of the Chemical Engineering Institute and the Institute of Natural Sciences. Pupils have an opportunity to be involved into the laboratory classes in certain areas of general, organic, analytical, and physical chemistry. In addition, they are able to master the basics of research and physicochemical park of devices and can be supported by the tutors in cognitive interest of the pupils and research.



Fig.3 The practical work for pupils.

Chemical tournaments and matches

Tournaments and matches have a reputation as effective technologies for the formation of cognitive interest in the subject. Team competitions of pupils help them to solve the complex chemical problem tasks and protect them in scientific discussions and chemical debates, and overcome the non-trivial situations. The«KVN» on a chemical theme is carried out once a year for pupils in specialized 10-11th grade of the schools of Ekaterinburg and Sverdlovsk region. Round selection of schools declaring their participation is organized. Finals hold at the UrFU.

What is the Tournament of Young Chemists (TYC)? TYC is command-private competition of pupils in their ability to solve complex chemical problem tasks and to provide solutions.

Goal of the tournament:

- the formation of pupils' interest in chemistry, involve them in practical research activities, training standards and style of work in the creative teams;
- strengthening interdisciplinary connections, activation of extracurricular activities in chemistry, and attracting scientists and graduate students to work with pupils, professional development of professor assistant and teachers.

Olympiad and tournaments have a similar target. It is the work with talented pupils. The most important difference in the tournament is a team competition. However, the structure of competition is arranged in such a way that during the “fighting” the level and the depth of knowledge of each team member are detected. Participation in the tournament team building requires its own strategy presentations, ability to formulate in an appropriate way and to ask questions, to summarize, and to give their own appraisal.

Objectives of the tournament have not clear resolution and require long preparation, and some of them allow only the fantastic solutions which could not be considered as the disadvantages. It more looks like a deliberate move, because of in solving such problems an ability of pupils to generalize facts, put forward their own ideas, logical reasoning and fantasize with modern scientific theories are fully manifested. One can often find a lot of the different literature, but it is usually impossible to find out a straight answer. It allows to approximate the process of working on a task to the research activities namely:

- a theoretical framework based on the analysis of literature data and consultations with experts;
- the nomination of its own concept, its interpretation and justification;
- critical review and discussion in the team;

– preparation and submission of the report.

Chemical competitions and Olympiads

Within the framework of the "Green Chemistry" project, competitions and contests for students in chemistry are provided. The purpose of these activities is to identify and to support the talented pupils in the field of chemistry in the Ural region. Besides, the competition of research projects of pupils at the institutes of the UrFU and the Ural Branch of the Russian Academy of Sciences (UB RAS) is planned.

The international Olympiad in organic chemistry for the pupils and the students was held in the new format in 2013/2014 academic year. Promotion of international cooperation and attraction of talented youth to the most pressing problems of modern science, enhancement of the prestige of the specialties chemical and pharmaceutical industries for the first time was achieved. Olympiad was held within the framework of the Ural Scientific Forum named "Modern Problems of Organic Chemistry". The first and second year students of the Institute of Chemical Technology of UrFU, including the guys who decided to study at our university from other countries within the framework of international cooperation, took part as well.



Fig.4 Dr. Larisa I. Rusinova with students of Institute of Chemical Technology

Innovative component of this Olympiad is its holding in three stages: distance, intramural, and intramural practical theory. Realization of the competition allowed the pupils of Ural region and from other countries who do not have an opportunity to participate in the event. Organization of the event helped pupils in their professional self-determination, formed the interest of the pupils to study the theoretical foundations of organic chemistry, attracted students to the actual problems of Theoretical and Applied Organic Chemistry and stimulated the training and research activities.




Fig.5 Chemical Olympiad for pupils

Acquaintance with science and industry

Tours to institutions of UrFU, UB RAS, and manufactures of the Sverdlovsk region is organized and supported by the "green chemistry" project. Pupils are introduced to modern technology, environmental background of manufactures, institutions instrumental base, and modern advances and research directions. The staff of the institutes carry out the demonstrations of the spectacular chemical experiments in schools by the mobile groups of UrFU specialists. The main purpose is to generate an interest in chemistry. Bright chemical shows are demonstrated at school and children's parties.



Fig.6 Technological laboratory at Russian Academy of Sciences

Support for teachers of chemistry

Change in quality of school education in recent years has shown that the quality of school education is not raised without the joint efforts of schools and universities. The UFU contacts with teachers of chemistry both directly - by working with specialized classes, and through the Association of chemistry teachers in Ekaterinburg. The main activities of the project are the advanced training courses (primarily for teachers from the Urals and the Sverdlovsk region), holding events in the conjunction with the Association of Chemistry Teachers and the educational and material support of chemical classes and clubs in schools. Master classes, seminars and round tables with the teachers of the Sverdlovsk region have as part of the International Olympiad in organic chemistry in 2013/2014 academic year. It has enabled to extend the area of cooperation with schools and to hold the informational, advertising, and educational campaigns.

References

Anastas, PT & Warner, JC 1998, 'Green Chemistry: Theory and Practice', *Oxford University Press*, Oxford.

Anastas, P & Eghbali, N 2010, 'Green Chemistry: Principles and Practice', *Chem. Soc. Rev*., 39, pp. 301-312.

Chupakhin, ON; Charushin, VN & van der Plas HC 1994, *Nucleophilic aromatic substitution of hydrogen*, Academic Press: NewYork.

Charushin, VN & Chupakhin ON 2004, 'S_N^H methodology and new approaches to condensed heterocyclic systems', *Pure Appl. Chem*., Vol. 76, No. 9, pp. 1621–1631.

Charushin, V. & Chupakhin, O 2014, 'Metal Free C-H Functionalization of Aromatics Nucleophilic Displacement of Hydrogen Series', *Topics in Heterocyclic Chemistry*, Vol. 37, IX, 283 p.

Lancaster, M 2010 *Green Chemistry: An Introductory Text*, Royal Society of Chemistry, Cambridge.

Makosza, M 2010 'Nucleophilic substitution of hydrogen in electron-deficient arenes, a general process of great practical value', *Chem. Soc. Rev*., Vol. 39, pp. 2855-2868.

Rectorate of Ural Federal University viewed 07 July 2014, http://urfu.ru/en/about-the-university/rectorate/.

Ural Federal University viewed 07 July 2014, http://urfu.ru/en/.