Denis Zhilin

Russia

Basic Structure of the Educational System

Russia is a Federal republic comprising 88 regions. It has a population of 142 million [1], with 14.3 million pupils attending schools [2].

The school system is unified all over Russia. Most of the schools are state schools, the number of private schools is negligible (0.073 million pupils). There is an 11-year education system: four years for Primary School (six- to ten-year-old pupils), five years for Secondary School Level I (that is called General Level) and two years for Secondary School Level II (that is called Complete Level). At Level II specialization takes place: pupils can choose classes, where several subjects are taught at advanced sub-level. All other subjects are taught at basic sub-level. A school can choose whether to teach five or six days a week (at Primary School usually five). Normally, pupils study 35 weeks a year.

The curriculum is made up of a Federal component (that is determined by the Federal Ministry of Education), a Regional component (that is determined by regional authorities) and a School component (that is determined by the school). The distribution between the components is shown in table 1. The requirements for knowledge and skills at the end of each level are determined by the State Standard for Education. The first Standard was approved in 2004 and now the second generation Standard is being elaborated.

Usually lessons begin at 8:30 or 9:00 a.m. and last 40-45 minutes (up to 35 minutes at Primary sector), depending on the school. The breaks between the lessons are 10-20 minutes long and the school day ends between 12:30 a.m. and 3:30 p.m. (depending on the grade).

Primary and secondary education is compulsory and children have to attend school up to 9th grade. Then they choose between Complete Secondary School (two years) and vocational education (three or four years). The common belief is that vocational education is for weaker pupils who have difficulties learning at school. After Complete Secondary School pupils can proceed with their education in tertiary institutions, choose vocational courses or find lower-qualified jobs.

Table 1: Number of lessons per week for each grade [3]

Grade	Age of pupils	Federal component	Regional component	School component	Federal component for subjects (basic/advanced*)				
					Chemistry	Physics	Biology	Geography	Natural science
Secondary school – complete level									
11	16	30	2	4	1/3	2/5	1/3	1/3	0/3**
10	15	30	2	4	1/3	2/5	1/3	1/3	0/3**
Secondary school – general level									
9	14	29	3/6		2	2	2	2	
8	13	30	2/5		2	2	2	2	
7	12	29	2/5			2	2	2	
6	11	27	2/5				1	1	
5	10	26	2/5						
Primary school									
4	9	22	0/3						2***
3	8	22	0/3						2***
2	7	22	0/3						2***
1	6	20	0						

* For advanced sub-level – only recommendations.

** Instead of Physics, Chemistry and Biology (choice of the school).

*** "Surrounding World".

There are a very small number of specialist chemistry schools or specialist Chemistry classes in ordinary schools. There are no official statistics, but we can estimate that no more than 5,000 pupils are taught there. However, a great number of them enter the best tertiary institutions and then become scientists or engineers in chemistry. Therefore, the importance of this small number of schools and classes for chemical education and Russian Chemistry in general is vital. Pupils in these schools or classes have four to eight Chemistry lessons per week (partly at the expense of the school component, partly – owing to cheating). Each of these schools, although they are public and officially comply with all the legislation, is very individual, with its own curriculum and didactic technique (that sometimes contradicts official ones). The curriculum is comprehensive, which is required by the Federal Standard for Education. To join such a school or class (at 7th, 8th or 9th grade) children have to pass an entrance examination. Usually they are taught by professional scientists, not by professional teachers. Very often they collaborate with tertiary institutions, using their laboratories and involving students. To

combine insight in science and abilities to teach, a teacher of such a school has to be an outstanding personality, so the number of such teachers is very small – approximately 30 all over Russia. The relations between these schools and local educational authorities are often ambiguous.

Elementary Sector

Pre-school children (57% of one- to six-year-olds in 2003 [4]) can attend kindergarten. It is a part of public education, but its main purpose is considered to be to release parents from taking care of their children during working hours. The kindergarten provides learning possibilities, but with no mandatory curriculum. Thus the possibilities depend on the kindergarten.

Primary School

Primary school comprises the age group from six to ten (grades 1 to 4) with 5.2 million pupils (2004). This is where pupils acquire basic knowledge in reading, writing, calculating and in a foreign language (usually English). Reading, Writing and Mathematics are the main subjects. Natural science is first taught within the subject "Surrounding World". The curriculum of the subject is not coherent, but introduces the basic concepts of natural science – water, soil, rocks, earth, weather, stars and planets, animals, the human body etc. Great attention is paid to hygiene and behavior in the environment. Social, historical and political concepts (e.g. family, behavior in society, the Constitution, the rights of a citizen, main steps of Russian history) are also introduced. Predominantly the course is literary – practical work is seldom carried out, despite the fact that the State Standard for Education requires simple skills in measuring, taking bearings, and "working with natural objects". No particular chemical concepts are introduced except for temperature, liquid, gaseous and solid state.

General competence requirements at the end of the fourth grade (according to the State Standard for Primary Education [5])

- The pupils are able to read to themselves and understand a text.
- The pupils are able to pick out the main idea of a text.
- The pupils are able to describe what they see.
- The pupils are able to group objects, according to common features.
- The pupils are able to compare objects to find common and particular features, and are able to make conclusions based on comparison.
- The pupils are able to execute simple algorithms.
- The pupils are able to work out the consequence of actions to solve a task ("What should I do and how?").
- The pupils are able to compare the result with a pattern ("Did I get a proper result?").

Competence requirements in natural science at the end of fourth grade for the subject "Surrounding World" (according to the State Standard for Primary education [5])

- Pupils know the main properties of water and air.
- Pupils know what is necessary for a living being.
- Pupils know the rules of personal hygiene.
- Pupils are able to determine the properties of natural objects (colour, shape, size).
- Pupils are able to distinguish between natural and artificial objects.
- Pupils are able to distinguish between the parts of a plant and to draw them.
- Pupils are able to give examples of representatives of different groups of plants and animals, and are able to describe peculiarities of their shape and mode of life.
- Pupils are able to show the continents, oceans, rivers and some cities on a map and on a globe.
- Pupils are able to use a thermometer to measure the air temperature.
- Pupils are able to find links between the seasons and life.
- Pupils are able to use methods of plant care.
- Pupils follow the rules of safe behaviour.
- Pupils are able to find links between human impact on nature and its consequences.

Secondary School – General Level

About 7.5 million pupils attend the general level of secondary education (5th-9th grade, 10- to 14-year-olds.). The requirements and the number of lessons for each subject are officially unified. However, there are different learning programmes with different contents that formally fulfill the requirements. The choice between the different learning programmes (of those officially approved) is the responsibility of the particular school. At the moment there are about eight approved programmes for Chemistry, however, this number changes very often. Surprisingly, their content and approaches are quite different (except for core concepts), because the requirements are vague. This vagueness is deliberate to allow such variations.

The natural sciences (biology, chemistry, physics and physical geography) are separated at the secondary general level and are taught individually. About ten years ago the subject "Natural Science" was introduced as an experiment. However, nobody managed to make it really integrated – it was still divided into parts, so this subject was finally removed from the learning programmes.

The state regulates when chemistry teaching should begin within the framework of the federal component. Most often chemical education begins in grade eight. It is mandatory for all pupils and is taught in two weekly lessons of 45 minutes duration.

Lessons taken from the school component could be used to begin chemistry education earlier. There are at least two experimental preliminary programmes introducing Chemistry at an earlier time. However, these programmes are not widespread. My personal opinion (there were no investigations on it) is that these programmes are theoretical and that is why they are ineffective. Specialized schools and classes, where chemistry education is introduced in the seventh grade, use their own programmes.

A great number of learning programmes describe the content and results of chemical education, but two approaches can be distinguished. The first approach is traditional and introduces basic chemical concepts, such as "substance", "mixture", "chemical reaction" etc. Then the substances are classified (oxides, acids, bases and salts) and reactions between them are discussed. Finally the periodic system is introduced after this and the chemistry of the elements is based on that.

The second approach is more academic and begins with the structure of atoms and principles of structure. Then, the chemistry of substances is presented based on these principles. There have been no real investigations to show which approach is more effective. My personal opinion is that the first one is more effective, because if a pupil does not understand what a substance is, he will never understand its structure.

Ion-exchange and redox reactions are taught in both approaches. The concepts of reaction rate, heat effect and chemical equilibrium are also introduced, but they are hardly used to discuss the way of reaction. The Standard requires a basic knowledge of organic chemistry (the structure of organic compounds and several classes of organic compounds) but the necessity of these requirements is still disputable. The opponents argue that it is impossible to teach anything coherently in such a very short time. This time would be better used for teaching general and inorganic chemistry.

The Standard requires some simple experimental skills. However, chemical experiments are not widely used. The reason is that chemistry laboratories were very poorly stocked between the end of the 1980s and 2005. In 2005 the national project "Education" started and within the project a lot of schools were supplied with equipment and reagents. However, after more than 15 years of poverty, the culture of chemical experiments has nearly disappeared and survived only due to some enthusiastic teachers. Now it is beginning to recover, but the process will demand time, resources and good management. The main problem is that many teachers are reluctant to introduce experiments (as well as any innovation).

General secondary level – the minimal content (a digest) [5]

- What is chemistry?
- How to investigate substances
- Safety rules in the laboratory
- Atoms, molecules, elements, mol, valency, oxidation number

- Calculation of: the mass or volume of one component based on the mass or volume of another; the mass portion of a substance in solution; the mass portion of an element in a substance
- Structure of the atom (electronic shell, protons, neutrons) and the periodic system
- Covalent, ionic and metallic bonds
- Chemical reaction, its conditions and features; classification of reactions
- Dissociation, ions, ion exchange reactions
- Metal, non-metal, oxides, bases, acids, salts
- Chemistry of elements (H, halogens, S, P, C, Si, alkaline and alkaline earth metals, Al, Fe)
- The fundamentals of the composition of basic compounds
- Hydrocarbons, alcohols, carboxylic acids, lipids, carbohydrates, proteins
- Calorie content of food, preservatives, domestic chemistry

Secondary School – Complete Level

Secondary education is compulsory, however, after the ninth grade pupils can choose between vocational courses and the complete level courses of secondary school. In vocational courses they get vocational training and study the necessary school subjects at the basic level of complete secondary education. In 2004 2.9 million pupils attended secondary school at the complete level.

At the complete level there are two sub-levels for each subject: basic and advanced. Usually there are classes offering an advanced study of natural, humanitarian and linguistic sciences, but that depends on the particular school. The system of individual courses exists in a very small number of schools.

For a very long time school education has finished with final exams. In the past Literature and Mathematics were mandatory and four other subjects were chosen by the school or by the pupils themselves. If a pupil wanted to attend a tertiary institution, he had to pass an entrance exam in three or four subjects. The list of subjects (usually including Mathematics) and the examination tasks depended on the institution.

Since 2009 final and entrance exams have been combined in the Unified State Exam (USE) that gives grounds for unfavorable criticism. The exam has three parts: Part A (multiple choice), Part B (matching exercise) and Part C (requires a founded solution). Parts A and B are checked by a computer, Part C – by experts. The advocates of the USE (mostly the educational officials) claim that it a) avoids corruption in the entrance exams, b) unifies the level of teaching, c) allows the comparison of results at different schools (and thus the quality of teaching in each particular school) and d) makes tertiary education more available for provincial pupils. Their opponents (advanced teachers and parents, lecturers of tertiary institutions) object that a) the corruption only shifts from the entrance commissions to the local educational authorities, b) the necessity for total unification is

disputable, c) the criterion of a teacher's work is the progress of each particular pupil, not the result and d) that institutions for physics, chemistry and biology are full of provincial students anyway. They add that one instrument is inadequate to solve two different tasks (to reveal pupils who did not achieve the minimal requirements and to find pupils who will be good scientists); that multiple choice tasks discourage the pupils from thinking and that teaching is replaced by practising and preparing for the USE. At any rate, the USE influences teaching (and the teaching of chemistry in particular) and one should take it into account.

In the framework of the USE there are two exams (in Russian and Mathematics) that are compulsory for everybody and three that can be chosen by the pupil.

Chemistry at complete basic level can either be an isolated course (one lesson per week) or can be incorporated into the course of Natural Science. However, those who study chemistry at basic sub-level do not choose chemistry in the USE, so there is no effective control of educational achievements and in fact there are no achievements. For this level there are even fewer Standard requirements than for the general level.

The requirements for the complete advanced level are much more complicated. However, the goals that are declared in the Standard are quite vague. At specialized schools the unofficial requirements are much higher than the requirements of the Standard.

Complete secondary advanced level – the minimal content of the general level (a digest) [5]

- Atom and electron: quantum numbers, orbitals, electronic configurations
- Coordination compounds
- Geometry of molecules
- Comprehensive theories of the structure of substances
- Solutions
- Enthalpy, entropy, Gibbs energy
- Mechanisms of reactions
- Solubility product, pH, hydrolysis
- Redox potentials, electrolysis, chemical sources of electricity, corrosion
- Types of chemical bonds in organic compounds and mechanisms of chemical bond breaking
- Ionic and radical mechanisms
- Alkanes, alkenes, dienes, benzene and the homologous series, alcohols, phenols, ethers, carbonic acids and their derivatives, esters, lipids, soap, carbohydrates, amino acids, peptides and their structure, nucleotides, RNA, DNA, polymers
- Chemical analysis and synthesis
- Chemical processes in living organisms
- General foundations of chemical technology, natural sources of chemical substances

- Polymers, new materials in engineering
- Pollution and its consequences
- Sources of chemical information

Examples of USE tasks [6]

Part A

In order of the elements Na → Mg → Al → Si

1) the number of valence electrons increases ☐
2) the number of electron layers decreases ☐
3) the number of protons in the nucleus decreases ☐
4) the atomic radii increase ☐

Part B

Establish a correspondence between the scheme of reaction and the change in the oxidation number of the oxidizer.

Scheme		Change in the oxidation number of an oxidizer	
A)	$MnCO_3 + KClO_3 \rightarrow MnO_2 + KCl + CO_2$	1)	$Cl^0 \rightarrow Cl^{-I}$
B)	$Cl_2 + I_2 + H_2O \rightarrow HCl + HIO_3$	2)	$Mn^{+VI} \rightarrow Mn^{+IV}$
C)	$K_2MnO_4 + H_2O \rightarrow KMnO_4 + MnO_2 + KOH$	3)	$Cl^{+V} \rightarrow Cl^{-I}$
D)	$Na_2SO_3 + KMnO_4 + KOH \rightarrow Na_2SO_4 + K_2MnO_4 + H_20$	4)	$Mn^{+VII} \rightarrow Mn^{+VI}$
		5)	$Mn^{+II} \rightarrow Mn^{+IV}$
		6)	$S^{+IV} \rightarrow S^{+VI}$

A	B	C	D

Part C

The following substances are given: sulphur, hydrogen sulphide, nitric acid (conc.), sulphuric acid (conc.) Write down chemical equations for four possible reactions between them.

Example of an entrance exam task to the Chemical Department of Moscow State University

70.1 g of sodium and rubidium bromide mixture were added to 786 ml aqueous solution of silver nitrate (concentration 0.7 mol/L). The precipitate was removed and an iron plate was put into the solution. When the reaction was complete, the mass of the plate had changed by 4.0 g. Calculate the mass portions of the bromides in the initial mixture.

Taking Stock of the Russian School System

It would not be an exaggeration to say that most Russian citizens are not happy with the school system. Many pupils hate school because for them it is useless and unpleasant; parents claim that many teachers are not qualified; teachers expect parents to build up a positive attitude towards studying; employers moan that the pupils' competences are decreasing; principals write an enormous number of stupid reports to local education authorities. In fact, the key person in the Russian school system is the teacher. If a school has a good team of teachers, most of the enumerated problems are solved.

The authorities understand this situation but the solutions are disputable. They try to solve the problem by increasing salaries. This wage increase depends on the teacher's efficiency. However, the ways of estimating this (the results of USE, Olympiads, intellectual competitions etc.) are very formal and seem to be inadequate. Polls among graduates (used by the "Soros Foundation" from 1998 to 2003) were later buried by bureaucracy. Also, the Russian legislation makes the discharge of unsatisfactory teachers practically impossible and the increasing salaries for both qualified and unqualified teachers do not encourage them to improve their qualification.

The disputes about content still exist and the Federal Standard did not settle them. Some of the authorities, parents and pupils claim that the curriculum is overloaded, the others – that it is so shrunk that it makes no sense. De facto this problem is solved by very different levels of the school.

Taking Stock of Current Chemistry Instruction

There are two ways to estimate the educational achievements and compare them with other countries: international tests (such as TIMSS and PISA) and International Chemistry Olympiads. The results of TIMSS 2003 showed that the achievements in Science were a bit higher than the international average [7]. However, TIMSS is not a good way to estimate the effectiveness of chemistry teaching, because the participants had only just begun to study chemistry. Russian teams have always achieved great success in the international Chemistry Olympiads. For example, in 2008 the Russian team took second place. The conclusion might be drawn that Russian methods of chemistry teaching are immensely effective, particularly for the best pupils, mainly due to the teachers' enthusiasm.

Despite apparently good results in international tests and Olympiads, the Russian society is not happy with chemistry teaching. However, it is very difficult to describe the problem correctly, because during the last 20 years nothing has been done to estimate the effectiveness of chemistry teaching and the pupils' attitude towards Chemistry. Thus, all the criticism of chemistry instruction is speculative. It