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(Chemistry)

Training of Engineers for Industrial Chemistry at the "Lensovjet" Technological Institute of Leningrad

The development of higher technical teaching in Russia, at its start, was closely linked to the problems of the chemical mining industry. Attention was given to the teaching of chemists even under Peter 1st, when specialists were trained in the field of mineral and metal analysis. Since the middle of the 18th century in Russia, under the initiative of M.W. Lomonossov, regular training of highly qualified chemists has been carried out. In a laboratory, well equipped for its time, students of Lomonossov carried out various projects in general chemistry, analytical chemistry, physical chemistry and applied chemistry. There was there a happy combination of physical - mathematical methods and chemical methods.

With that, the rigorously quantitative principle was dominant in research carried out in the laboratory. Followers of Lomonossov became chemists well versed in mathematics and physics.

In 1755, the opening of Moscow University made possible the training for the country of a large number of highly qualified specialists, including chemists. Moscow University contributed to the training of researchers and professors who, in turn, made possible the creation of new schools of higher learning in Russia. The first school of higher technical learning in Russia was the Institute of Mines at St. Petersburg, opened in 1774, where students were taught the mining industry at the same time as chemistry and the principles of chemistry in metallurgy.

At the beginning of the 19th century, the country was greatly in need of engineer-technologists, owing to the rapid development of chemical enterprises, mainly those which served the textile, leather and sugar industries. An Institute of Technology was opened at St. Petersburg in 1828 where mechanical technologists and chemists were trained who followed interlocking curricula and programs. Students at the Institute learned among other things, physics, practical chemistry, technological chemistry and mechanics. In the organization of the teaching of chemistry at the Institute, a big role was played, without a doubt, by one of its founders, the father of thermal chemistry, G.Y. Guess.

Fifty years later, that is in 1879, students of the Technological Institute were learning 32 subjects. Most of the subjects were taught according to the same program. They were higher mathematics, physics, inorganic chemistry, thermo dynamics, resistance of materials, applied mechanics, technology of metals, technology of construction materials, technical design, drafting, architectural art, architecture, geodesy, foreign languages, political economy and other subjects related to chemistry and mechanics.

Later courses were introduced in electrical technique, physical chemistry, chemical technology and chemical processes and apparatus.

The student chemists also learned supplementary subjects such as: analytical chemistry, organic chemistry, technology of mineral substances, anatomy and physiology of plants, minerology, technology of organic substances, technology of food, technology of coloring materials.

At the Technological Institute, teachers were D.I. Mendeleev and many other scholars -- the metallurgist Tschernow, author of a reference work on organic chemistry, F.F. Beilsteine, the physical chemist G.I. Guess, technologists S.S. Andriev, A.K. Kroupsky, S.V. Lébédev, P.O. Fédotjev, N.L. Chtchoukine, the eminent chemists A.A. Jakovkine, A.E. Favorsky, A.E. Poray-Kochits, D.P. Konovalov, N.I. Kourbatov, physicians B.L. Rosingue and R.E. Lents and others.

The main characteristics of technological education in Russia before the revolution were (2): training of technological engineers, chemists and mechanical engineers on an interlocked curriculum over the first three years; fundamental instruction in general theoretical subjects and general engineering subjects; close co-ordination between theoretical teaching and practical work in the laboratories, the shops, the mills and the manufacturing plants. It should be noted that chemical engineers were graduated with wide capabilities and possessing deep knowledge of mechanical subjects and that mechanical engineers had a good knowledge of the essentials of technological processes.

Higher technological instruction in pre-revolution Russia had made some progress.

In different parts of the country three technological institutes were opened (at Petrograd, Kharkov and at Tomsk) as well as four technological faculties in technical schools. Shortly before World War I these institutes had an enrolment of 10,000 students and the number of graduating engineers was 200-230 per year. This represented a smaller number than a single graduation in 1957 at the "Lensovjet" Technological Institute of Leningrad.

In 1918, the Lenin decree On Admission to the Higher Learning Establishments in the R.F.S.S. stipulated that "the first places must incontestably be reserved for people drawn from working classes and poor peasants, to whom the state scholarships will be granted on a large scale".

Having opened wide the doors of its establishments of learning to all men and women from all nationalities, and having done away with the tuition fees and given scholarships to a large majority of the students, including without exception, all those who were in need, our progressive state has achieved in a short time complete democratisation of the school of higher learning and has ensured its rapid development.

At the present time there are in the country more than 750 higher learning establishments, of which 195 are technical schools, with a total registration of 700,000 students. Almost all large cities in the Soviet Union have become centers of higher technical learning; in many establishments the teaching is given in the language of the local nationalities.

The training of chemical engineers was intensified following the startling progress of this industry in the U.S.S.R..

At present, we have some 40 technological institutes and as many engineering faculties in polytechnic institutes and others which, in 1955, graduated 4654 in chemical engineering, 1635 in forestry, lignin, cellulose and paper technology; 3454 in the technology of food, textile and light industries and a large number of mechanical engineers. Moreover, the technological institutes have trained a large number of scientists - in chemical and technical science.

The admission tests to the schools of higher learning include the following examinations: the candidate's native language and literature, mathematics, physics, chemistry and one foreign language.

As a rule there are always several candidates for each vacancy in the Technological Institute of Leningrad.

2. Training of Engineers for the Chemical Industry

A characteristic of the chemical industry is that the investment in equipment and motive power is proportionately much larger than in other industries.

In 1940, the investment in equipment in the chemical industry in the U.S.S.R. was 32,000 rubles per worker and was thus about 10 times larger than in the textile industry, and twice as large as in the metallurgical industry. (7) In the chemical industry, modern machinery and automatic controls for chemical processes are constantly being introduced. The modern technical engineer must, therefore, be well trained, not only in the field of chemistry and chemical technology, but also in the new techniques of automation, utilization of isotopes, etc. (2) The curriculum for technical engineers at the Lensovjet Technological Institute of Leningrad has been the subject of important changes in accordance with the requirements of a changing industry.

Before the revolution, almost 65% of the time in the engineering course was devoted to engineering science. At that time a practising technological engineer was obliged to carry out the duties of a construction engineer.

In the 1930's more attention was paid to specialized subjects, to which 25% of the course was devoted.

This practice arose from the increasing demand for specialized graduates qualified to go to work immediately in the wide variety of new plants and factories.

In the last few years the Soviet technological institutes were entrusted with the training of specialists with a wide range of knowledge. In this respect, in the curriculum at the Lensovjet Technological Institute of Leningrad, almost half of the time is spent on theoretical subjects, about one-third on engineering subjects and only 13.6% on specialized subjects.

Owing to the special subjects taught at the Lensovjet Technological Institute of Leningrad, chemical and mechanical engineers are trained to work both in straight chemical industries and also in plants which use chemical techniques to a large degree. (The petroleum industry, coke industry, food, textile and light industries, building material industries, machinery and measuring instruments etc.) The graduate from the Institute is also equipped to work on planning and in scientific research. Because of the variety of work in which he may be engaged, the graduate from the Institute is required to have broad technical knowledge, a thorough knowledge of higher mathematics, physics, chemistry, electrical engineering, electronics, chemical engineering processes and equipment, strength of materials and other engineering subjects.

The diversity of technical processes and the equipment necessary for them, the application of automation and the variety of measuring and control equipment, requires creative effort on the part of the engineer during his studies. It is necessary for him to know how to analyse and tabulate the results of the operation of equipment, machines, and various installations, as well as to devise, on the basis of experimental data, new technical processes and new equipment or improve those already existing, with a view to increasing production and lowering production costs.

In accordance with these requirements the curriculum of the Institute is designed to graduate specialists with a wide range of knowledge.

Education at the Institute is set up on a curriculum for each special subject and this controls the list of subjects and the order in which they are taken, the dates of the tests and examinations, and of the period of indoctrination. For the majority of subjects the course lasts for 5 years; for certain very difficult subjects - 5-1/2 years.

Table No. 1 outlines the curricula followed at the "Institut technologique Lensovjet" in Leningrad, designed to graduate technological, chemical, and mechanical engineers.

Table No. 1 - Curricula of "L'Institut technologique Lensovjet" - Leningrad.

	SUBJECTS	Chemical Engineers	Mechanical Engineers
1.	Social, economic, and humanitarian sciences	6 624 14.0	6 624 14.0
2.	Physics and mathematics	3 660 14.9	3 156 17.0
3.	Chemistry	5 1,110 25.0	1 320 7.2
4.	Applied mechanics	7 850 19.0	8 1,530 34.5
5.	Applied chemistry	4 452 10.1	7 614 13.8
6.	Special subjects	4 600 13.6	3 460 10.3
7.	Physical education and sport	1 136 3.2	1 136 3.2
	Total: Subjects	30 4,432	29 4,440
	% of total	100.0	100.0

Subjects in the social, economic, and humanitarian group include the history of the Communist Party of the Soviet Union, political economy, history and logic, industrial economy, the organisation and planning of industrial enterprises, and one foreign language.

Physics and mathematics include - mathematics, physics, and mechanical theory.

Chemistry includes general, inorganic, analytical, organic, physical, colloidal chemistry.

Applied mechanics includes descriptive geometry, technical design, resistance of materials, mechnaical theory, parts of machines, thermal technique, electrical technique, construction and metallurgy.

Applied chemistry includes general chemical technology, processes and equipment of chemical industries, automation in chemical industries, safety practices and corrosion of metals.

Special subjects comprise courses in chemistry and technology regarding the special subjects, as well as courses in mechanical equipment of industries in the particular category. Particular attention is given to the study of industrial installation, and the construction of machines and equipment used in the chemical industry.

The principal methods of instruction are - lectures, seminars, practical work, and periods in thelaboratories, shops, and in industries.

The timetable is set up on a basis of 6 hours per day. Work in laboratories, shops, drafting rooms and lecture rooms is also planned so as to assure the student the greatest amount of independence and initative. During his education the student has to complete calculations and drawings, and to attend lectures regarding his work in the laboratory.

At the end of each semester there is a period of examinations in the subjects included in the curriculum. Tests in the course of the curriculum have to be taken by the student after he has completed calculations, drawings, and practical work in the laboratory.

No additional time is set aside in the curriculum to take the tests, which have to be completed before the examinations in the course of the study periods.

Three or four weeks are set aside for the examination period which takes place at the end of each semester. During this period the student has to take a maximum of 5 examinations.

To devolop habits of individual work and methods of starting projects and do the engineering connected with them, the curricula require students to work out problems in thermal technique and economy and to complete projects at the end of the year dealing with questions about machine parts, processes and equipment in chemical technology, special technology, etc. etc.

The drawings of each project represent from 3 to 5 sets of ordinary designs.

In the course of his studies at the Institute the student is sent three times to modern industrial establishments to work there.

At the end of the third year he spends 4 weeks in his first general introduction to practical engineering work at the establishment. During this time students take note of the plant economy, its electrical supply, water supply, the operation of boiler rooms, the repair of mechanical equipment at the transportation machine shops, as well as in certain technological production procedures.

Near the end of the 8th and 9th semesters the student takes his technological initiation and a term ordinarily preceding the graduation work, each lasting 8 weeks.

During the technological course the students acquaint themselves with processes of production as well as with methods of quality control of raw materials, materials in process and finished products. During this the student works with technological graduates and in plant laboratories.

During practical work which precedes graduation, and which takes place in plants whose specialty is similar to the proposed future work, the students acquaint themselves with the technology as well as the work done in the main and auxiliary shops of the plant, the technological documentation, the distribution of personnel, the economics of production, and the organization of maintenance services.

The knowledge gained during this course is of great value to the student who is preparing his graduation thesis. The students are sent on course in conformity with a contract signed between the Institute and the firm.

The planning of the thesis for graduation, or the execution of the research work constitute the final phase of study. The subject of his thesis is given to the student before his graduation term.

The 10th semester is devoted entirely to planning or to the research work.

The subjects for the thesis are suggested to the students keeping in mind the needs of the industry, and in most cases deal with complete plant projects. The project consists of establishing material and thermal requirements for production, calculations regarding special apparatus, transportation facilities, and communications. At the same time, a report on the economics of the project is prepared, to justidy the approximate cost of the building and equipment, distribution of personnel, costs of raw material, steam, electric power and finally the cost of production, and factors concerning automation, production control and safety measures.

Work on this project also includes production flow sheets, plans of the building showing the location of equipment, construction plans of one or two important pieces of equipment and an automation plan of an industrial installation. This part of the project contains 7 to 9 pages of ordinary drawings. The part containing the economic study together with the calculations varies from 80 to 120 pages.

Students showing aptitude for scientific research are given subjects on chemistry or production technology.

Graduation theses are presented publically by the students in the presence of the State Examination Commission whose chairman is in most cases a technical engineer or well known contractor. The appreciation of the work is given by an experienced engineer in that particular field, who is officially designated to analyse the work. Having successfully supported his work the student is granted the title of 'Technical Engineer'.

Institutes of higher learning already possessing some experience produce engineers according to their own curricula. The plan at our institute takes into account besides the general program of study, mechanics, electricity, and automation of chemical plants, the application of atomic energy and of new materials available to the industry.

The individual curricula, not including those at the technological institutes or polytechnic institutes, are based on scientific aims and interests of the faculty and also on pedagogical traditions.

The quality of education is in large measure dependent on the development of the scientific research work directed by the professors. Each professor who directs laboratory work and gives the lectures does also the scientific work. This work is financed in the institute by the state and also by firms according to their economic contracts.

To have an idea of the scientific work done at the Institute let us look at the following examples.

The chemical industry equipment faculty looks into the problem of automation of chemical processes. The Faculty of technology of inorganic chemistry carries out research in Kinetics of heterogeneous processes. The Faculty of processes and equipment studies the kinetics of typical processes of chemical technology. The Faculty of electro-chemistry studies the mechanics of electric crystallization. The Faculty of glass carries on scientific work regarding the production of glass at low temperatures and studies the electric properties of glass. The Faculty of nuclear physics studies the photonuclear reactions on heavy nuclei, as well as problems on radioluminescence. The Faculty of general chemistry studies synthesis methods and the physico-chemical properties of complex combinations of series of elements.

As we have indicated, important research work of the faculties is financed by industry. For instance, in 1957, under contracts signed between the Institute and industry, research work carried out by the Institute would be valued at 9 million rubles.

In 1957 important scientific research laboratories were created at the Institute under the faculties of nuclear physics, analytic chemistry, and organic chemistry; laboratories equipped with modern facilities, with research personnel complementing the existing staff in such a way as to make possible work on large scale scientific problems, conforming to the specialties of the faculties. Similar laboratories have now been opened under other faculties.

Students, members of the student society on scientific research, and students preparing their graduate theses, participate in the research undertakings of the faculties.

A professor of known ability, takes scientific charge of this student society. The students report on the results of their research work during the course of the annual scientific meeting of the Institute. The best work is awarded the Prize of the Minister of Higher Education of the USSR.

The Institute periodically organises scientific conferences between universities dealing with the branches of science in which the chairs of the Institute have obtained notable success. For example, one could cite the recent conference concerning questions of absorption, and the preparation of solvents, enamels, complex compounds, the theory of colour and the synthesis of colours, at which numerous soviet chemists took part.

In 1957 the Institute called a scientific and methods conference of all the universities concerning the teaching of analytic chemistry in the establishments of the teaching of higher education, regarding the question of the introduction of new physico-chemical methods of research in the analytic chemistry programme.

The results of scientific research and scientific methods are published. Since 1957, the institutions of the higher technical learning (in Moscow and Ivanovo) have been publishing scientific reviews which publicize the work of the chemists from the establishments of higher learning of the USSR.

In 1957 the participating members of the Institutes published 36 monographs and manuals -- the whole making 458 pages of printed matter. Also 13 publiciations of "Work by the Technical Institute 'Lensovjet' of Leningrad" were issued (138 pages of printed matter), and a considerable number of articles were published in the scientific journals of the country.

3. The Students and Their Organizations

Most of the students (about 80%) get scholarships which increase from year to year. The best students get increases up to 25%.

In effect, however, every student can receive an allocation through the Students' Society.

the administration of the Institute organized at its own expense a recreation camp in a wooded area.

Various student organisations function at the Institute, their representatives taking part, on an equal footing, with the Institute Council.

A large role is played by the Student Syndicates, which include all the students at the Institute. The syndicate committee elected each year by secret ballot, is the directing body of the syndicate organization. This directing body controls the various activities of all the students through its committees: a study committee, cultural committee, a committee concerned with living conditions, etc., as well as through the Syndicate offices in the faculties.

The teachers are responsbile for the day to day education of the students, and their task is not only to instruct the young, but to inculcate in them the best human virtues: diligence, respect for man, and the fruits of his labor, a sense of duty, and a spirit of internationalism.

A students' journal is published at the Institute -- "Technologue" -- with a very large circulation, as well as several intermural journals which reflect all the events in the life of the Institute and of the country.

It is especially in the activities of the amateur artistic clubs where the cultural education work of the student organizations is manifested. At the Institute 500 young men and women under the direction of professional artists, participate in choral groups, work in theatrical studios, take lessons in classes for solo singers and pianists, play in the folk-music club, the dance club, the painting studio, etc.

Students readily go for sports; they take part in all kinds of competitions and games; 817 students are engaged in 20 sections of the sports club of the Institute, as follows:- Mountain climbing, football, volleyball, gymnastics, swimming, boxing, athletics, skiing and hockey; 1890 students practise sport outside these sections, the greater part of them are members of the students sport society.

The Technological Institute "Lensoviet" of Leningrad, together with other technological institutes, train technological, chemical and mec hanical engineers for the chemical industry. The chemical engineers work in chemical plants, in plant laboratories and in scientific research institutions, in the development of projects and as professors in schools of higher learning. The mechanical engineers work in chemical plants, in mechanical construction plants and also in the development of projects.

The education of engineers at the Institute is conceived in such a manner as to enable graduates from the Institute, engineers or chemists, to operate all kinds of apparatus without difficulty and to make it possible for mechanical engineers to find their way easily in chemical processes. They are all educated following the scientific traditions of the national school of higher learning and, at the same time, are initiated into the progress of science and the cultural advancement in the world.

All facilities are given at the Institute to develop freely individual faculties, scientific aspirations of the young people, the formation of their characters and their physical development. Each year through the doors of the Institute there pass hundreds of young specialists, who enter into life, carrying with them their knowledge and the culture of conscientious citizens.

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CERTAIN TRENDS IN THE DEVELOPMENT OF CHEMISTRY AND THE CHEMICAL INDUSTRY IN THE U.S.S.R.

N.N. Melnikov

During recent years, chemical science and the chemical industry of the Soviet Union have made very considerable progress, one indication of which is the launching of the first artificial Earth satellites. It would have been impossible to launch these satellites without the participation of the chemical industry, for modern rocketry places heavy demands on the chemical products and materials that it uses. All these materials are successfully produced by the Soviet chemical industry.

Some idea of the development of the U.S.S.R. chemical industry may be gained from the following facts; the volume output of the chemical industry in 1956 was 4.7 times that of the prewar 1940 level. In some of the categories the growth in production is still greater. The percentage increase in 1956 over that of 1940 is as follows: in artificial fibres -,1160, in plastic masses -855, in automobile tires - 376, in mineral fertilizers -336, sulphuric acid -271, etc.

A still more rapid development in the chemical industry is envisaged for the coming years with considerably greater appropriations for the construction of new plants. As in previous years, investments will be made in those branches of industry that make for a higher living standard of the people. High priority will be given to the production of fertilizers and chemicals for protecting plants. This will help to raise crop yields and thus expand the output of food products and also the industry of artificial fibres, plastic masses and other materials directly concerned with the output of consumers' goods.

The successful development of the chemical industry is directly due to the extensive research conducted by a very large number of research institutes, chemical plants, and by the Academy of Sciences.

In a brief report it is impossible to encompass all the multifarious trends in scientific investigation and all the achievements of chemical production, for they are bound up with the output of many thousands of products and materials produced by the chemical industry of the country, and are the result of the study of thousands of chemical reactions and processes.

At the present time the chemical industry of the Soviet Union produces all the principal modern products and materials required by allied branches of industry and by agriculture. These include synthetic fibres, modern plastic materials on the basis of exceedingly diverse compounds, chemical means of protecting plants (DDT and its analogues), phosphoro organic preparations, organic compounds of mercury, different phenols, hexachloro-cyclohexane and many others, chemicals for fighting weeds (2,4-D and its derivatives, IPhC, ClIPhC, trichloro-acetates, esters of polyethylene-glycol, etc., dyes, pharmaceutic preparations, antibiotics, and many others. Ethyl alcohol and other substances are produced in large quantities from petroleum gases.

However, like in any normally growing organism there is an extra demand for certain products; this makes it necessary to develop still more rapidly the production of a series of new materials, The exceedingly rapid development of agriculture calls for a fast and expanded output of products necessary in the obtaining of higher yields.

The rapid development of the chemical industry became possible due to the organization of a broad network of research institutions both in the various branches of industry as well as in the Academy of Sciences, and the academies of the union republics.

From the very first years of Soviet power, higher educational establishments encouraged the development of the old schools of science and also began to create, one after the other, new scientific research organizations whose aim was to promote, (through scientific research) the development of the different branches of industry of inorganic and organic chemistry. Among these organizations are the following: The Russian Institute of Applied Chemistry(later renamed the State Institute of Applied Chemistry), The Karpov Physico-chemical Institute, The Institute of Fertilizers (now the Scientific Institute of Fertilizers and Insecto-Fungicides, or NIUIF), The State High-Pressure Insitute, The Scientific Institute of Semi-products and Dyes, The Chemical Pharmaceutic Institute, The Plastics Institute, and institutes of artificial fibres, of the nitrogen industry, of synthetic caoutchouk, rubber, synthetic alcohols, and many others.

Without touching on questions concerning the development of physical and inorganic chemistry by the schools of such brilliant investigators as N.S. Kurnakov. I.A. Kablukov, P.A. Rebinder, A.N. Frumkin, N.N. Semenov, G.G. Urazov, I.V. Grebenshchikov, I.I. Chernyaev V.G. Khlopin, A.N. Terenin, V.I. Vernadsky, A.P. Vinogradov, I.P. Alimarin, I.V. Tananaev, S.I. Volfkovich, and many others, I shall attempt to give a broad picture of some of the trends in the field of organic chemistry.

First in this field are the works of the numerous followers of N.D. Zelinsky and A.E. Favorsky on different transformations of aliphatic, alicylic, and aromatic hydrocarbons. Of great technical significance is the reaction of dehydrogenation of different hydrocarbons, which can be used as a basis in the production of such products as styrene, butadiene, methylstyrene, ethylene, propylene, acetylene, and many others. Hydrocarbon transformations of this type have been studied in sufficient detail by N.D. Zelinsky and A.A. Balandin and their coworkers. As you know, the first of these hydrocarbons serve as raw material for the production of certain important types of synthetic rubber.

It may be mentioned that due to the work of S.V. Lebedev and his school the USSR was the first country in the world (1932) to organize a large-scale industrial production of synthetic rubber. In this important field of industry, priority undoubtedly belongs to the Soviet chemists and technologists. At present the Soviet Union produces a large number of different synthetic rubbers, each with its specific peculiarities suited to the different fields of technology. At present, only the U.S.S.R. is producing industrially butadiene-methylstyrene rubber, which has properties not inferier to butadiene-styrene rubber. Synthetic rubbers have also been developed on the basis of other hydrocarbons too, and also acrylic rubbers, vinyl-pyridine (that stand up well under low temperatures and swell less in organic solvents), polyurethane rubbers, and many others. Vinyl-pyridine rubbers are obtained by means of the copolymerization of butadiene and 2-methyl-5-vinyl-pyridine and retain elasticity in the temperature range from -55 to +200°C. Of great interest is isoprene rubber which was synthesized in the U.S.S.R.

In recent years, increasing importance is being attached to siliconic caoutchoucs, the rubbers of which retain their properties in the temperature range from -60 to +250°C. These rubbers are also stable under the action of ultraviolet radiations, water, ozone, and many other chemical and physical agents. Rubbers have also been found that do not lose their properties at temperatures over 300°C, which is a significant factor making them useful in various new branches of technology.

Besides the rubbers already mentioned, the U.S.S.R. produces many other types obtained by copolymerization of dienes with unsaturated halogeno derivatives of hydrocarbons and with other unsaturated compounds containing different functional groups. Also in production is butyl rubber.

Of the reactions of the transformation of different classes of hydrocarbons, mention should be made of the reactions of aromatization of aliphatic hydrocarbons, which are of interest in a number of processes concerned with amelioration of motor fuel, and also the synthesis of certain homologues of benzene. Again exceedingly interesting are the reactions of alkylation of hydrocarbons in the presence of boron fluoride and other catalysts, the isomerization of aliphatic and cyclic hydrocarbons with the inter-transition of six- and five-membered cycles (B.A. Kazansky, N.D. Zelinsky et al.), hydrogenation, oxidation, halogenation, nitration, sulfochloration, etc.

The diverse catalytic transformations of hydrocarbons studied by Soviet chemical schools have served as material for the development by A.A. Balandin of the multiplet theory of heterogeneous catalysis, which is based on the principle of a structural and energy correspondence between the substrate and the catalyst.

The reaction of the nitration of cyclohexane and its analogues which was developed by S.S. Nametkin and his coworkers may be utilized for the industrial production of polyamides. An interesting technical method of obtaining polyamides on the basis of the reaction of telomerization has been developed by A.N. Nesmeyanov, R. Kh. Freidlina and their coworkers. The reaction of carbon tetrachloride with ethylene and a series of subsequent transformations have served as a basis for obtaining a new type of synthetic fibre - "enant" and "pelargon." In addition to synthetic fibre, plastificators, lubricants, and aromatics have been synthesized from the products of the reaction of ethylene and carbon tetrachloride and have been studied.

In this case, amino-enanthic acid and amino-pelargonic acid are obtained according to the following scheme:

$$Cl(CH_2)_n CCl_3 \rightarrow Cl(CH_2)_n COOH \rightarrow NH_2(CH_2)_n COOH \quad (1)$$

Methods for the synthesis of α-amino acids have been worked out. These include natural amino acids (proline, ornithine, lysine, glutaminic acid, α-amino-adipinic acid, α-amino-suberic acid,
(1) phenylalanine, p-chloro-phenylalanine etc.) and their homologues and analogues. All these acids are easily obtained by the general scheme:

$$Cl(CH_2)_n CH_2CCl_3 \qquad Cl(CH_2)_n CH=CCl_2 \qquad X(CH_2)_n CH=CCl_2 \quad (2)$$

$X(CH_2)_nCHClCCOOH \quad X(CH_2)_nCHNH_2COOH$

A new type of telomerization was recently discovered by A.N. Nesmeyanov and R.Kh. Freidlina in the case of the reaction of ethylene and methyl-dichloro-silane, phenyl-trichloro-silane, triethyl-silane, etc.:

$$RSiHCl_2 + nCH_2{=}CH_2 \rightarrow R\underset{Cl}{\overset{Cl}{Si}}(CH_2CH_2)_nH \qquad (3)$$

An extensive cycle of studies of the transformations of acetylene compounds was carried out by the school of A.E. Favorsky. Here, mention should first of all be made of the numerous and interesting investigations of I.N. Nazarov and collaborators and M.F. Shostakovsky on the synthesis and study of the transformations of different vinyl ethers.

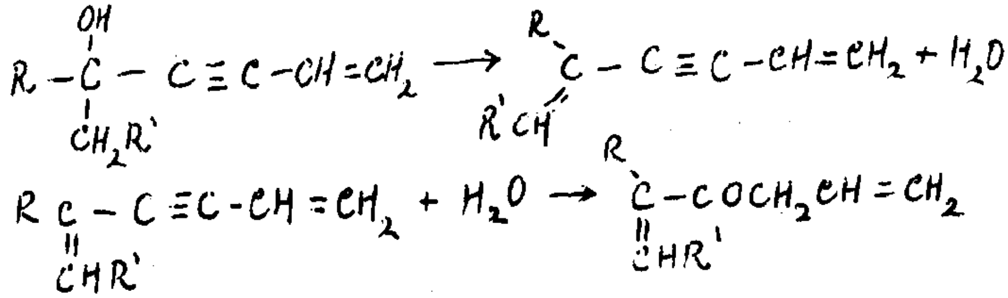
Among the reactions of acetylene hydrocarbons discovered by Favorsky, one of the most interesting is their condensation with cetones. This reaction proceeds in the presence of powdered potassium hydrate, and in the simplest case may be represented by the scheme:

$$CH_3COCH_3 + HC{\equiv}CH = (CH_3)_2C\begin{matrix}-OH\\-C{\equiv}CH\end{matrix} \qquad (4)$$

In the condensation of acetone with vinyl-acetylene we obtain vinyl-acetylenyl-dimethylcarbinol, which readily polymerizes with the formation of polymers with good adhesion properties, which fact made it possible to utilize it for the production of a so-called carbinol glue.

Starting with this and analogous alcohols, Nazarov and coworkers carried out a large number of different syntheses of unsaturated substances, cyclic and heterocyclic compounds.

The cycle of transformations accomplished by Nazarov and coworkers may be represented by the following general schemes:



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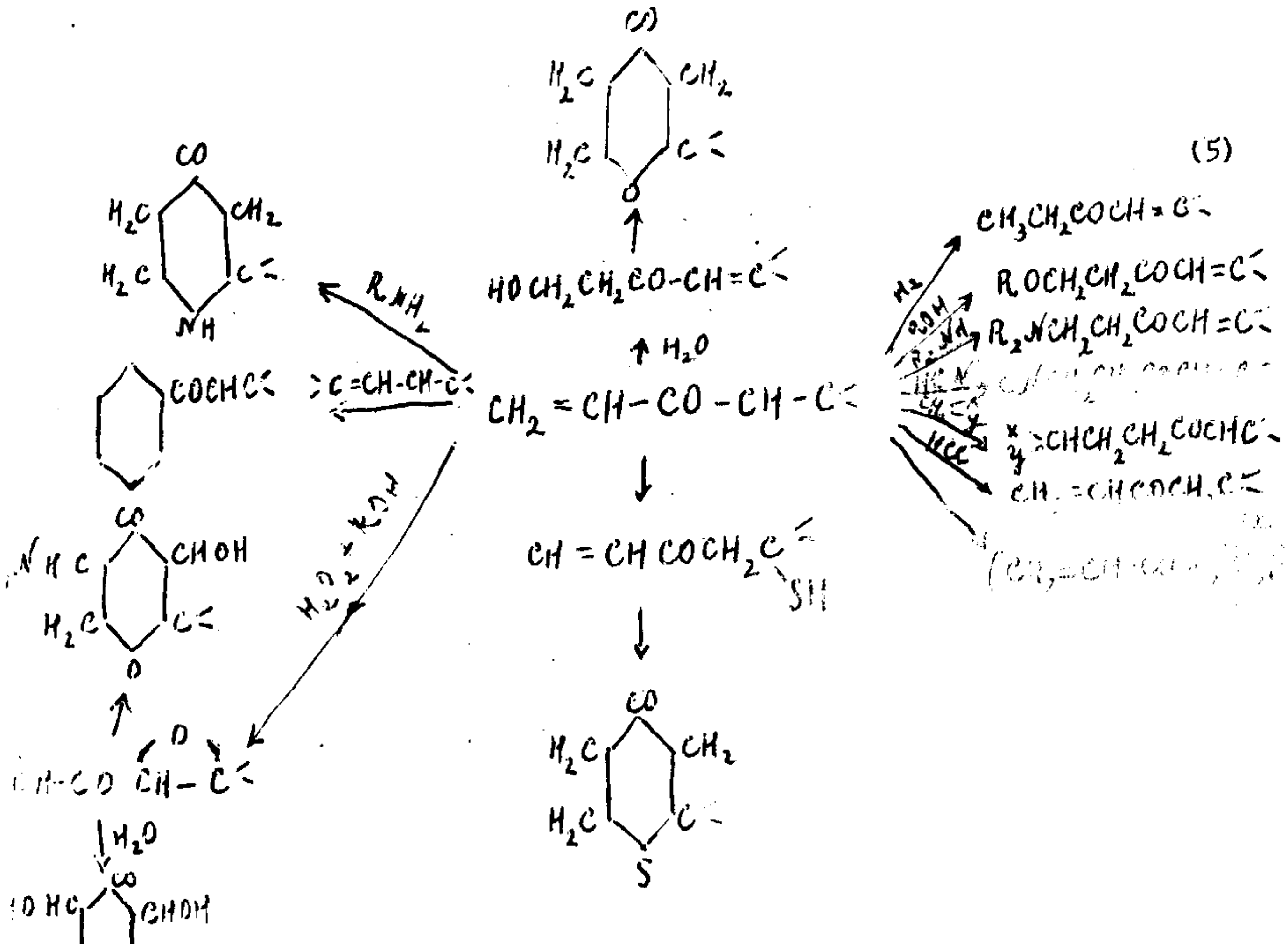
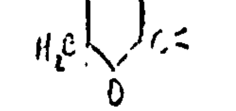


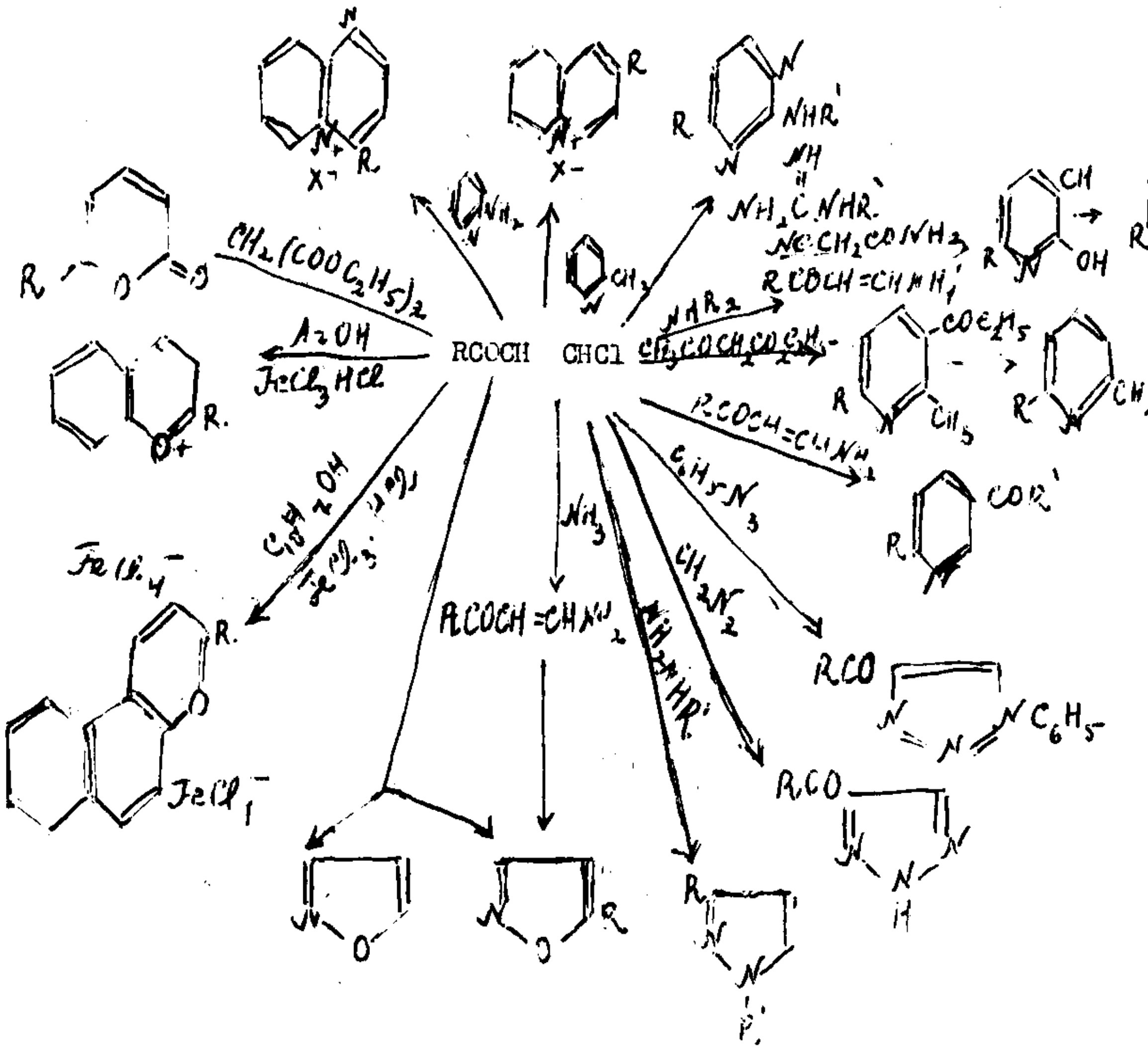


Utilizing vinyl-alkyl-cetones in the reactions of the diene synthesis, Nazarov and coworkers [illegible] synthesized substances close in structure to the natural styroids.

The application of the diene synthesis for the synthesis of polycyclic systems has made it necessary to study the structural directivity of these reactions. In a large number of examples it was possible to show that the conditions of the reaction and the character of the substitute in diene and dienophil produce an essential effect on the course of the process and the structure of the final products of the reaction. In working out the reaction of guided synthesis of stereoisomers it was possible to obtain all four of the theoretically possible isomers of octaline-4-dicarboxylic acid and seven out of eight possible decaline-1,2-dicaroboxylic acids.

Interesting investigations into the synthesis of a large number of different heterocyclic compounds were carried by A.N. Nesmeyanov, N.K. Kochetkov and others. The initial products of these syntheses were β-chloro-vinyl-alkyl-ketones. Some of the trends of transformations of β-chloro-vinyl-alkyl-ketones are given in the general scheme on page 10.

Extensive research has been conducted in the U.S.S.R in the processing of petroleum hydrocarbons, both for their use as motor fuel, lubricants, and also for processing into diverse chemical products. Of the products of the chemical processing of natural gases and petroleum hydrocarbons, mention should first be made of the synthesis of halogeno derivatives of hydrocarbons, alkylene oxides, surface-active substances, lower and higher alcohols carboxylic acids and other technically important products. In this trend, mention should be made of the work of S.S. Nametkin, A.V. Topchiev, B.A. Kazansky, N.I. Shuikin, K.P. Lavrovsky, and others.



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In addition to the study made of [redacted] aliphatic compounds and their application in industry, much has been done on derivative [redacted] aromatic hydrocarbons that are needed in the production of dyes, pharmaceutic preparations, and chemical means of protecting plants and fighting weeds.

It is to be noted that [redacted] the Soviet Union as early as 1949 organized a large-scale industrial production of [redacted] phenol via the peroxide of isopropylbenzene, and at the present time this method is [redacted] used to produce phenol at a number of chemical factories (P.G. Sergeev). Further investigations showed that this method may be used to obtain other phenols and ketones too.

Among works of a practical nature mention should [redacted] be made of a method of producing 2,4-dichloro-phenoxy-acetic acid by chloration of [redacted] water [redacted] dispersion of phenoxy-acetic acid in apparatus with mixers of original design; the same method is used to obtain a 90% yield of 2-methyl-4-chloro-phenoxy-acetic and butyric acids.

Of interest also is the photochemical production of hexachloro-cyclohexane in [redacted] high-power column apparatus. The technical hexachloro-cyclohexane obtained in the photo-chemical chloration of benzene may be processed in one stage into a preparation containing 90% gamma isomer with a yield of not less than 85-90%, taking account of the gamma isomer in the technical product. The nontoxic isomers of hexachloro-cyclohexane are good [redacted] raw materials for the production of a number of valuable products that may be used both in agriculture and in industry.

Speaking of the processing of [redacted] aromatic compounds, mention should be made of the development of the analine-dye industry and first of all of the production of dyes. During the postwar period the chemical industry began to produce a large number of new dyes, among which are 47 direct(substantive) 11 coloured sulphurous,, 16 products for cold dyeing, 68 acid and mordant-type for wool, 7 basic, 41 pigment and lacquer-type, 42 ~~cubic~~ vat, etc. These figures show that only during the past few years the chemical industry has begun to put out over 250 new dyes that belong to different classes of organic compounds. Simultaneously with the growth in assortment of dyes and pharmaceutic preparations there developed an industry that produces semi-products necessary for their synthesis.

On the basis of aromatic raw material, large-scale production (with a large number of different types) has been organized of polymer materials, including synthetic fibre and plastic masses, in addition to dyes and pharmaceutic preparations. We may also point to the large-scale production (on the basis of aromatic compounds) of chemicals for the protection of plants, such as DDT, trichlorophenolate of copper (for cotton-seed treatment against hommosis), poly-halogeno-phenols, dinitroalkylphenols and many others.

Investigations of element-organic compounds have been greatly extended in recent years. Russian chemists have been interested in metallo-organic compounds since the time of A.M. Butlerov. Some of the most outstanding representatives of Russian chemical science, such as A.M. Zaitsev, S.N. Reformatsky, P.P. Shorygin, N.D. Zelinsky, and many others have worked in this field and have made their contribution to the development of this important branch of organic chemistry. Interest in this field is due to the important part which element-organic compounds play in the solution of many problems of theoretical and applied chemistry. Suffice it to recall that such important discoveries as establishing the valency of the elements, the discovery of free aliphatic radicals, the obtaining of new stable materials, and others resulted from investigations in the field of element-organic compounds. Also well-known is the role of many metallo-organic compounds in organic synthesis and their highly diversified application in different branches of industry and agriculture. Thus, they find application as raw material for the production of materials that are very resistant and stable with respect to aggressive media, as antiknock agents for motor fuel, admixtures to lubricants, insecticides, fungicides, seed-treatment agents, herbicides, and in many other cases.

During recent years in the Soviet Union, investigations have been made of the organic compounds of the following elements: lithium, sodium, magnesium, zinc, cadmium, mercury, boron, aluminium, thallium, silicon, titanium, zirconium, germanium, tin, lead, chromium, selenium, phosphorus, arsenic, antimony, bismuth, bromine, iodine, fluorine, iron, and platinum.

Outstanding in their investigations in the field of element-organic compounds in the U.S.S.R. are the schools of A.E. Arbuzov, A.N. Nesmeyanov, B.A. Arbuzov, I.L. Knunyants, K.A. Kocheshkov, and others.

To date, a large number of methods have been worked out of the synthesis of different element-organic compounds; numerous types of new compounds have been obtained and many of them have found practical applications. The abundance of new material has made it possible to draw certain fundamental conclusions that are of importance not only for the chemistry of element-organic compounds, but for all organic chemistry as well.

Below we give several illustrations of the synthesis of element-organic compounds.

The synthesis of element-organic compounds by means of double onium salts discovered by Nesmeyanov in 1929 has been widely applied for the synthesis of organic compounds of mercury, thallium, tin, lead, bismuth, arsenic, antimony (Nesmeyanov, Kocheshkov, Markova, Reutov, and coworkers). In its general form, the reaction of obtaining element-organic compounds by this method may be represented by the following general scheme:

$$(ArN_2X)_m MeX_n + \frac{2m}{p} Me' \rightarrow Ar_m MeX_{n-m} + \frac{m}{p} Me'X_p + N_2 \quad (7)$$

This method is a general and simple way of obtaining individual metallo-organic compounds containing diverse functional groups in the [redacted] aromatic radical.

In connection with the investigation [redacted] of the diazomethod a study has been made of the decay mechanism of [redacted] diazonium and other onium compounds; it is shown that it is possible to control the reaction and to [redacted] guide its course either according to the ionic or the radical type.

Very interesting results have been obtained in studying the decomposition of boron fluoride of[redacted] phenyldiazonium in [redacted] chlorobenzene and bromo-benzene. In this respect it was possible to synthesize hitherto unknown simple aromatic compounds of polyvalent chlorine and bromine:

$$ArN_2BF_4 + ArX \rightarrow Ar_2X^+BF_4^- + N_2 \quad (8)$$

By [redacted] substituting other anions for the anions of boron fluoride, Nesmeyanov and coworkers made a [redacted] study of a large number of salts of diphenylchloronium and diphenylbromonium. The double salts of diarylhalogonium with the salts of metals were also used to synthesize organic compounds of mercury, tin, antimony, and bismuth[redacted] (Nesmeyanov, Reutov, Makarova).

$$(Ar_2XCl)MeCl_n + \frac{2m}{p} Me' \rightarrow Ar_m MeX_{n-m} + \frac{m}{p} Me'X_p \quad (9)$$

The diazomethod was applied by N.N. Melnikov, K.D. Shvetsova-Shilovskaya and Grapov to obtain mixed esters of thiophosphoric acids:

$$(RO)_2P(X)SH + ArN_2Cl \rightarrow (RO)_2PXSAr + N_2 + HCl \qquad X = S, O \quad (10)$$

The same authors developed a method of synthesizing esters of arylphosphinic acids from dialkylhalogenophosphites and the respective salts of diazonium:

$$(RO)_2PCl + ArN_2Cl \rightarrow (RO)_2PCl_2N_2Ar \xrightarrow{H_2O} (RO)_2P(=O)Ar + N_2 + 2HCl \quad (11)$$

Of great importance in the chemistry of element-organic compounds are reactions linked by transitions from one set of element-organic compounds to other sets. Nesmeyanov and coworkers have developed numerous pathways of such transitions, especially between the organic compounds of mercury, on the one hand, and compounds of zinc, cadmium, aluminium, thallium, tin, lead, arsenic, antimony, bismuth, and polyvalent iodine, on the other hand.

Kocheshkov and coworkers recently worked out a method of the direct introduction of thallium into the aromatic ring:

$$C_6H_6 + Tl(OCOC_3H_7\text{-}i)_3 \rightarrow C_6H_5Tl(OCOC_3H_7\text{-}i)_2 + i\text{-}C_3H_7COOH \quad (12)$$

An interesting method of the synthesis of metallo-organic compounds is the reaction of metal substitution recently worked out by Kocheshkov and Talalieva:

$C_6H_5Li + Mg$ (and also Hg, Sn, Pb, As, Sb) $\rightarrow$

$\rightarrow (C_6H_5)_2Mg$ (and also $(C_6H_5)_2Hg$, $(C_6H_5)_4Sn$, $(C_6H_5)_4Pb$, $(C_6H_5)_3As$, $(C_6H_5)_3Sb$) (13)

A new method of the synthesis of organic compounds of mercury of the aliphatic series was worked out by G.A. Razuvaiev and coworkers:

$$CH_3CO_2HgOCOCH_3 \rightarrow CH_3HgOCOCH_3 + CO_2 \quad (14)$$

This reaction is initiated by peroxides.

The Frankland-Dup[illegible]s method has been used in the U.S.S.R. for the industrial production of seed-treatment agents. Due to the work of N.N. Melnikov and coworkers this method has produced yields of dialkyl mercury up to 70-90% of the theoretical value. In connection with the industrial production of mercuric agents for seed treatment, Nesmeyanov, Melnikov, and coworkers have made a rather detailed study of the reaction of dialkyl and diaryl mercury with mercuric salts of acids of different basicity. As a result of these investigations it has been possible to find conditions for producing alkyl-mercuric salts of poly-basic acids with yields close to the theoretical values.

The syntheses have been worked out of substituted alkyl mercuric salts by combining the salts of mercury with unsaturated compounds (Nesmeyanov, Frei[illegible]lina, Borisov).

The classical method of obtaining organic compounds of phosphorus is the Arbuzov rearrangement discovered by A.E. Arbuzov as far back as the beginning of this century. During recent years this method has been used to synthesize a large number of new compounds some of which are of great practical importance for use as medical preparations. New directions in the Arbuzov rearrangement have been discovered. As you know, the Arbuzov rearrangement is still the basic method of synthesizing aliphatic organic compounds of phosphorus.

Recently, B.A. Arbuzov and A.N. Pudovik worked out a new method of producing organic compounds of phosphorus by combining dialkyl-phosphites through double linkage of unsaturated compounds; this method has been used to synthesize over one hundred different compounds.

$$(RO)_2PHO + \rangle C=C\langle_Y \xrightarrow{RONa} (RO)_2\overset{O}{\overset{\|}{P}}-\overset{|}{\underset{|}{C}}-CH\cdot Y$$

Abramov, a [redacted] pupil of A.E. Arbuzov, [redacted] has made a study of the reaction of dialkyl-phosphites with aldehydes which was the basis in the production of the well-known insecticide depterex, obtained by condensation of dimethyl-phosphite with chloral. And the reaction of obtaining dimethyl-phosphite from phosphorus trichloride and [redacted] methanol may be combined with the joining of chloral.

A.E. and B.A. Arbuzov and coworkers made[redacted] a detailed study of the production of pyrophosphates, [redacted] thiopyrophosphates, dithiopyrophosphates and their different derivatives.

A method has been developed for the obtaining of different phosphorus compounds by the interaction of halogeno phosphorus with [redacted] ethylene oxide, aldehydes and the like(M.I. Kabachnik).

$$PCl_3 + 3\ \underset{\diagdown_{O}\diagup}{CH_2-CH_2} \rightarrow P(OCH_2CH_2Cl)_3$$
$$PCl_3 + RCHO \rightarrow R\underset{Cl}{\underset{|}{CH}}-POCl_2 \qquad (16)$$

A.V. Kirsanov discovered a new class of organic compounds of phosphorus obtained by the interaction of [redacted] halides of phosphorus with sulfamides and amides of different acids

$$ArSO_2NH_2 + PCl_5 \rightarrow ArSO_2N{=}PCl_3 \rightarrow ArSO_2N{=}P(OR)_3 \qquad (17)$$

Among the obtained compounds there are interesting [redacted] system insecticides that are practically harmless to warm-blooded animals.

In connection with the great importance of the different derivatives of thiophosphoric acid, which find wide application in agriculture as active insecticides and acaricides, of great significance is the obtaining of esters of chloro-thiophosphoric acid. Melnikov and Mandelbaum and coworkers have worked out a number of new and simple methods of obtaining these compounds. The most important of these methods may be represented by the following general schemes:

$$PSCl_3 + 2ROH + 2NaOH \rightarrow (RO)_2PSCl + 2NaCl + 2H_2O$$
$$ROPSCl_2 + R'OH + NaOH \rightarrow (RO)PSCl(OR') + NaCl + H_2O$$
$$2ROPSCl_2 + (R'O)_2Mg \rightarrow 2(RO)PSCl(OR') + MgCl_2 \quad (18)$$
$$3PSCl_3 + 2Al(OR)_3 \rightarrow 3(RO)_2PSCl + 2AlCl_3$$

Especially good yields are produced by dimethylchloro-thiophosphate and methylethylchloro-phosphate, on the basis of which a number of insecticides are produced. A distinguishing feature of these methods of obtaining dimethyl- and methylethylchloro-thiophosphates is the fact that the reaction proceeds with an almost equivalent quantity of the appropriate alcohol in the presence of a hydrous alkali.

A study of the properties of PFCl$_3$, alkyldichloro-thiophosphates and dialkylchloro-thiophosphates has shown that these compounds have properties that differ but slightly from the chloro anhydrides of different other organic and inorganic acids, on the basis of which a method has been worked out to obtain dialkylchloro-thiophosphates through the interaction of PFCl$_3$ or alkyldichloro-phosphate and the appropriate alcohols by the reaction:

$$PSCl_3 + 2ROH \rightarrow (RO)_2PSCl + 2HCl$$
$$ROPSCl_2 + R'OH \rightarrow (RO)PSCl(OR') + HCl \quad (19)$$

The same method may be used to obtain dialkylchloro-thiophosphates with different hydrocarbon radicals.

Of great interest are the works on tautomerism of the organic compounds of phosphorus, for example, the tautomerism of esters and other derivatives of phosphorous acid discovered several decades ago by A.E. Arbuzov and verified by his school on extensive experimental material, and also the works of Nesmeyanov and Kabachnik on the [redacted] dual reaction ability of organic compounds which was studied in detail by them in reactions of [redacted] various derivatives of the acids of phosphorus and certain other compounds.

It may be noted that an extremely rapid development of work in the field of silicon-organic compounds began after K.A. Andrianov discovered [redacted] polymer [redacted] silicon-organic compounds. In work conducted together with numerous coworkers, Andrianov showed the polymer character of the products of hydrolysis of mixed silicon-organic compounds and worked out a large number of ways of synthesizing these compounds. At the present time, [redacted] organic compounds are used to produce diverse materials such as varnishes, rubbers, plastics, etc. There is no doubt that this field of industry of polymer silicon-organic compounds will continue to develop at a very high rate, because (in many cases) silicon-organic polymers possess exceedingly valuable properties as compared with other polymer products.

The second important stage in the development of the chemistry of high-polymer silicon-organic compounds is the discovery by K.A. Andrianov and A.A. Zhdanov of a new class of polymers — poly-organo-metallo-siloxanes. The structure of this group of polymers may be represented by the following general formula:

$$-Si-O-Al-O-Si- \qquad -Si-O-Cu-O-Si-O- \qquad (20)$$

Polymers of this sort possess valuable properties and have already found practical application in industry. They readily dissolve in organic solvents, after the evaporation of which they form films. [redacted]

To this same group belong the work on the synthesis of the organic compounds of titanium which was conducted by Nesmeyanov, Freidlina, Nogina, and Brainina, who obtained different esters of titanium acid of the following structure:

$$(RO)_3Ti-O-Ti(OR)_2-O-Ti(OR)_3 \qquad (21)$$

During recent years considerable development has been apparent in the chemistry of the organic compounds of fluorine, which are of great practical and theoretical interest. In the U.S.S.R., studies in this interesting field are developing in several directions both as to methods of obtaining these substances and reactions of different substances of this class and as to their practical utilization in industry. First to be mentioned here is the work of I.L. Knyuyants and coworkers dealing with a method of obtaining fluoro alkanols by the interaction of alpha-oxides and hydrogen fluoride:

$$\underset{O}{CH_2-CH_2} + HF \rightarrow FCH_2CH_2OH \qquad (22)$$

Knyuyants and his coworkers have also made a broad investigation of numerous reactions of the linking of nucleophilic and electrophilic reagents to fluoro-olefines, they have studied the order of combination of alcohols and mercaptans to unsymmetrical fluoro-olefines, they have established facts of the vinyl substitution of fluorine atoms by alkoxyl and they have shown allyl rearrangements of perfluoro-allyl derivatives.

These same investigators have made a study of the reaction of nitration of different fluoro derivatives of ethylene and its homologues; and it has been established that in addition to dinitro-compounds, and sometimes in preference to them, there are formed

β-nitroperfluo-alkylnitrites, which upon saponification produce α-nitroperfluo-carboxylic acids.

$$CF_2NO_2COOH \qquad CF_3CFNO_2COOH \tag{23}$$

Unlike the ordinary α-nitroalkylcarboxylic acids, such acids are completely stable and are distilled without decomposition.

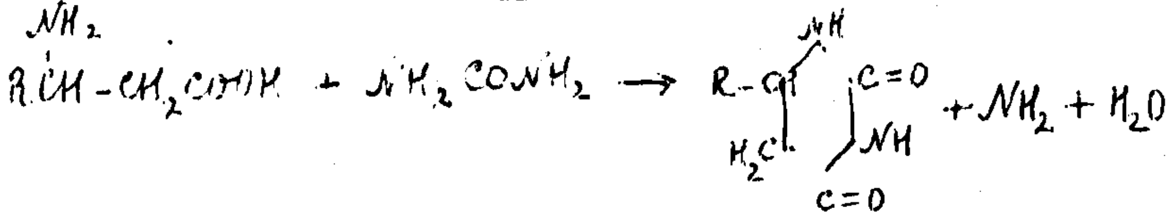
Perfluo-vinylmagnesium-halogenides too have interesting properties, through the utilization of which it was possible to obtain perfluo-acrylic acid and other compounds (Knynyants, Fokin, and others).

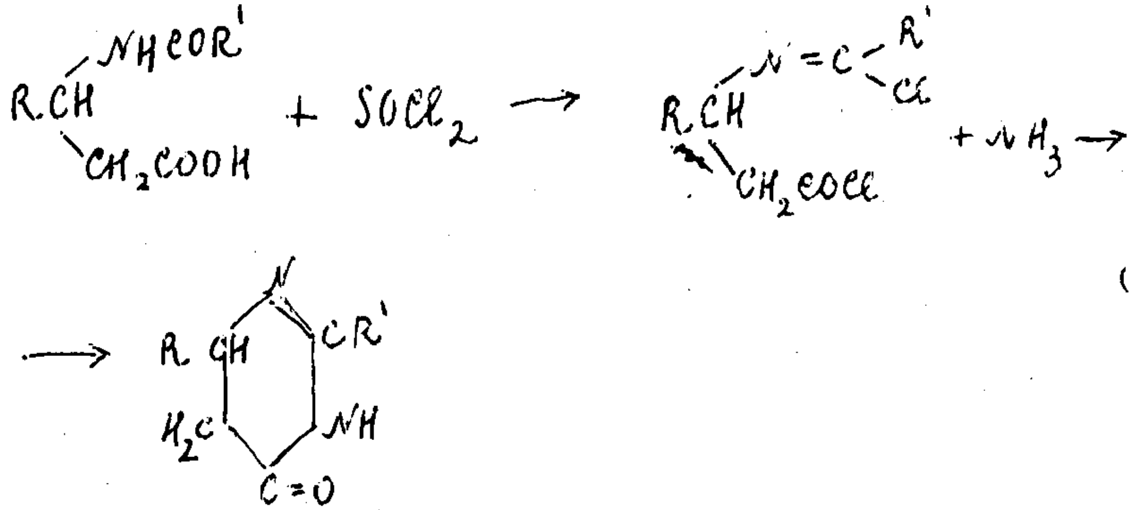
Extensive research has been conducted in the U.S.S.R. also in the field of the heterocyclic compounds of various series. These investigations are connected with the names of the Soviet chemists V.M. Rodionov, I.L. Knynyants, Iu.K. Iuriev, A.E. Porai-Koshits, B.A. Porai-Koshits, M.V. Rubtsov, Giller, Mndzhoyan, Ya.L. Goldfarb, and others.

It is impossible in a brief report to cover all the diversity of work being carried on by Soviet investigators in this interesting and important field, I shall therefore mention only a few that are of a general nature. Mention should first be made of V.M. Rodionov and coworkers. On the basis of a general method, discovered by him, of obtaining β-amino acids by means of the interaction of aldehydes and ammonia and malonic ester:

$$R.CHO + NH_3 + CH_2(COOH)_2 \rightarrow R.CH(NH_2)-CH_2COOH + CO_2 + H_2O \tag{24}$$

he developed a simple and convenient method of obtaining hexahydropyridines. The production of such compounds may be represented by the following scheme:





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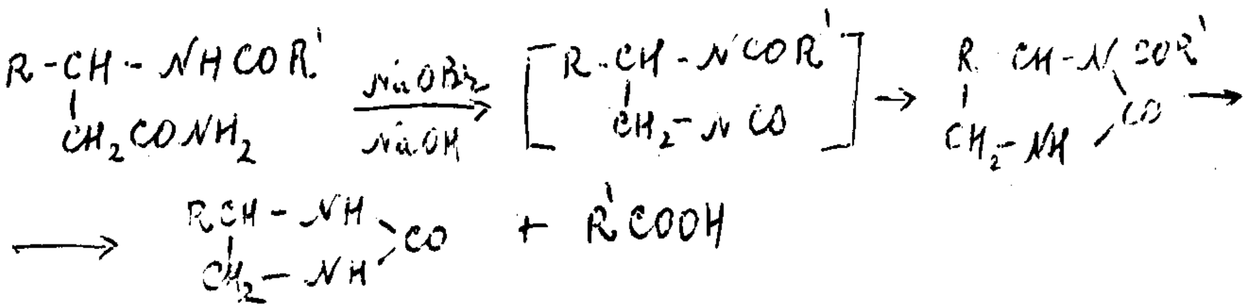


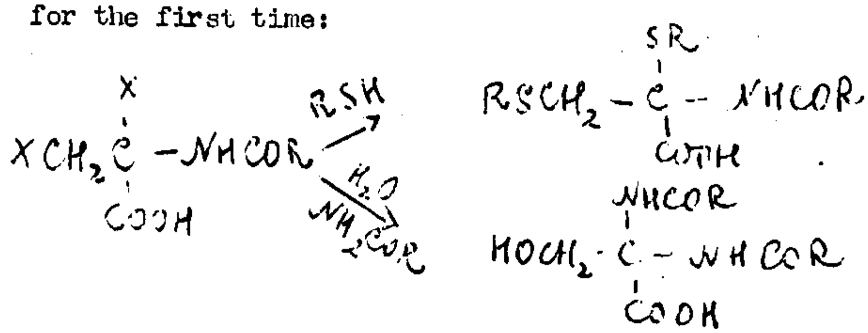
The significance of β - amino acids for living organisms is well known.

Speaking of the synthesis of amino acids it is necessary to point to the works of I.L. Knunyants and coworkers devoted to obtaining and studying β-oxy-α amino acids, which showed that β-substituted- α -acyl-amino acids are easily obtained from α-,β -dihalogeno-α-acyl-amino acids through the interaction of the latter with water, alcohols, mercaptans and other such compounds:

$$X-CH_2-\underset{COOH}{\overset{X}{C}}-NHCOR \xrightarrow{HY} YCH_2-\underset{COOH}{\overset{Y}{C}}-NHCOR + HX \qquad (26)$$

Y = OH, OR, NHR, SR, NHCOR

The second atom of the [redacted] haloid element is [redacted] subtstituted in more rigorous conditions. It was in this way that the -substituted derivatives of serine and cistein were obtained for the first time:



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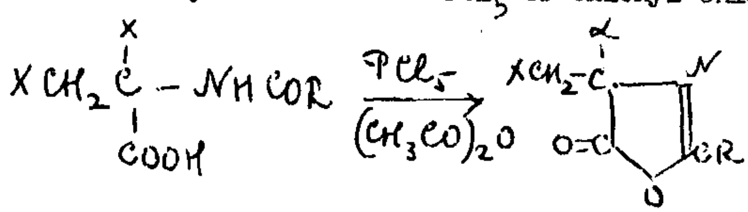
New oxasalons that contain in the position of the 4-oxasolon ring different functional groups have been synthesized by means of anhydridization of α- ,β -dihalogeno-α-acyl-amino-[redacted] carboxylic acids with PCl_5 or thionyl chloride:



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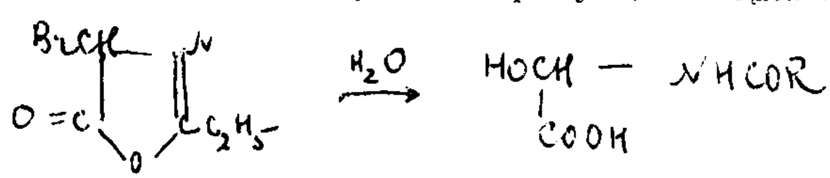
M.M. Shemyakin developed a method of obtaining α-oxy-α -acyl-amino acids by hydrolysis of 2-phenyl-4-bromoxasalons:



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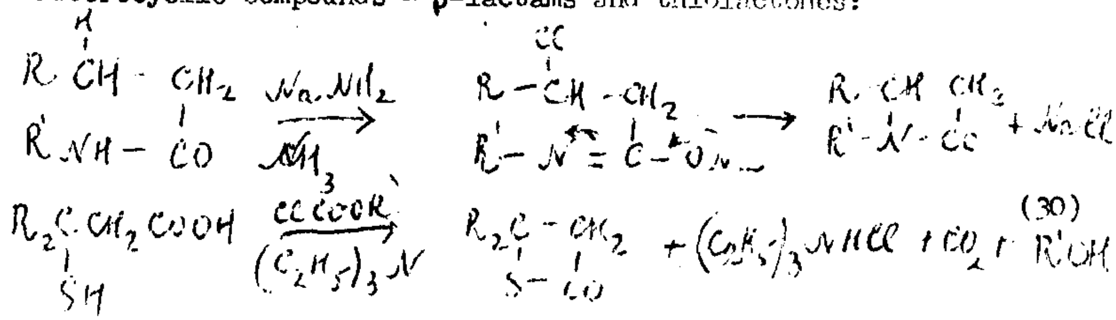
Interesting results have also been obtained by [redacted] Knunyants and coworkers in the synthesis of [redacted] four-membered heterocyclic compounds - β-lactams and thiolactones:



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In such a brief review as this is it was hardly possible to indicate even all of the principal trends of Soviet investigators in synthetic organic chemistry. I was therefore compelled to give only isolated illustrations that were in large measure selected subjectively, which was inevitable because of the tremendous abundance of the material. But I believe that the examples given are sufficient to show that serious attention in the U.S.S.R. is paid to the development of organic chemistry, and to the natural-chemical industry of organic synthesis, which plays an important part in satisfying the demands of the people for vitally important goods and materials.

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