Preface

DOI 10.1515/zpch-2016-5007

Kev Minullinovich Salikhov

The worthwhile problems are the ones you can really solve or help solve, the ones you can really contribute something to. **Richard Feynman**

When curiosity turns to serious matters, it's called research. **Marie von Ebner-Eschenbach**

Who would better illustrate the meaning of these two quotes than our friend and mentor, Kev Minullinovich Salikhov, director of the Kazan Physical-Technical Institute (KTPhI)? With his characteristic way of clear thinking and driven by his insatiable curiosity he entered new research fields, illuminating novel and long-standing scientific problems with remarkable patience and endurance.

In appreciation not only of his outstanding contributions to the subjects ranging from Chemical Physics and Magnetic Resonance to Physical Chemistry, but also of his services to the scientific community in general and in particular the EPR community, the present issue of the Zeitschrift für Physikalische Chemie is dedicated to Kev Salikhov on the occasion of his 80th birthday.

Following a good academic tradition, this special issue is intended to mirror some of the impact, Kev Salikhov has had on science over so many years. Thus, it is not surprising that EPR and NMR are at the core of this issue. Each of its manuscripts contributes one beautiful aspect of these fascinating topics that so much benefit from Kev's own scientific work. We wish to thank the authors for helping us collecting all these different facets.

Dear Kev, on behalf of all the authors we congratulate you for your achievements and we wish you all the best for both your scientific as well as your personal future. Please continue to convert curiosity into world-class research.

The Guest Editors

Gerd Buntkowsky
TU Darmstadt
e-mail: gerd.buntkowsky@chemie.tu-darmstadt.de

Konstantin Ivanov
ITC Novosibirsk
e-mail: ivanov@tomo.nsc.ru

Hans-Martin Vieth
FU Berlin
e-mail: hmvieth@zedat.fu-berlin.de

Biography of Prof. Kev Salikhov

Kev Minullinovich Salikhov was born on November 3 of 1936 in Krasnaya Rechka, Republic of Bashkiria (USSR, now Russia). He graduated from the Kazan State University, Department of Physics and Mathematics in 1959 and moved to Leningrad (now St. Petersburg) for a PhD program at the Institute of Macromolecular Compounds of the Russian Academy of Science (RAS). Kev's supervisors were Prof. Mikhail Volkenshtein and Prof. Yuly Gotlib. In those days Kev's research interests were in theoretical polymer physics. In 1963, Kev Salikhov received his PhD (thesis title: "Some aspects of molecular theory of dielectric and mechanical relaxation properties of polymers"). Afterwards he moved to the Institute of Chemical Kinetics and Combustion of the Russian Academy of Science (ICKC) of the Siberian Branch of RAS in Novosibirsk (Russia), where exciting research activities (greatly inspired by academician Vladislav Voevodsky) were carried out dealing with various aspects of chemical physics, chemical kinetics and spectroscopy, notably, magnetic resonance spectroscopy. Together with a nice working atmosphere this provided a young talented scientist (which Kev Salikhov was in those days) excellent conditions to establish his own research profile and to actively cooperate with various experimental groups.

Answering to the question "Who were the most influential of your scientific teachers?" Kev Salikhov says: "My most influential teachers were my family, and my teachers in high school (teacher of history – Tatiana Maksimova, of mathematics – Vera Yusupova, of Deutsch – Ivan Fresen), Prof. Semen Altschuler from Kazan State University, the supervisors of my candidate of sciences thesis Mikhail Volkenshtein and Yuly Gotlib, academician Prof. Vladislav Voevodsky in Akademgorodok. In fact, I always find I learn a lot from my colleagues and their teaching. Each seminar is like a lesson for me. So my "schools" were in Kazan, Leningrad, Akademgorodok (Novosibirsk), and Berlin." As scientists who influenced him Salikhov names Prof. Yakov Frenkel and Prof. Nikolai Bogolubov, mentioning that he personally likes their scientific style.

During his work at ICKC Kev Salikhov has made seminal contributions to several fields of research and demonstrated an amazing capability to obtain breakthrough results in different subject areas. He has made a pioneering contribution to studies of Heisenberg spin exchange. Notably, a general theoretical approach to spin exchange has been developed, i.e. kinetic equations have been proposed describing spin exchange in encounters of paramagnetic particles of different kind (free radicals, paramagnetic ions, triplet molecules). An intriguing effect, the Salikhov shift originating from spin motion during the diffusional encounter of particles in solution, has been predicted and confirmed experimentally about 25 years later. So, in this field Kev Salikhov was very much ahead

of time. In 1973 Kev has defended his habilitation thesis (title: "Kinetics of processes conditioned by spin-spin interactions of particles in magnetically diluted systems"). Prof. Yuri Molin, the director of the institute, says: "We, the experimentalists at ICKC, for many years were very lucky to work together with Kev Salikhov, an extraordinary theoretician. He has that incredible gift of easily communicating with colleagues when discussing enigmas that puzzled us in experiments, and putting forward new ideas."

One more exciting area of research was EPR spectroscopy, notably, pulsed EPR, which was actively developed in Novosibirsk in those days thanks to the experimental efforts of Anatoli Semenov, Yury Tsvetkov, Alexander Milov, Arnold Raitsimring, Valery Yudanov, Sergey Dikanov and Sergey Dzuba. Kev Salikhov obtained several exciting new results in this field: he showed that spin echo signals decay due to "instantaneous diffusion" and spectral diffusion induced by the dipole dipole spin-spin interaction. He has proven theoretically the possibility to observe spin echo modulations in disordered solids and was the first to elucidate the role of selective excitation of the EPR spectrum for the modulation pattern of the echo signal decay (ESEEM). Together with colleagues from ICKC, Alexander Milov and Mikhail Shirov, as early as in 1981, Kev Salikhov proposed the PELDOR technique (sometimes called DEER). Approximately two decades later this technique has become one of the standard and most useful tools in EPR. Presently PELDOR is frequently used as a standard "ruler" to measure distances in the nm range in a variety of systems, including biological systems. Prof. Sergey Dzuba says "Kev Salikhov was one of the persons from whom I learnt what the electron spin echo is. It was the time when I was a young student, while he was already an established scientist. We worked at neighboring laboratories so I and my young colleagues had a lot of possibilities to talk with him. Also, reading of his excellent book "Electron Spin Echo and its Applications" has helped us a lot in our studies. Therefore, I consider him as my teacher. Later, I admired how deeply he is involved in real scientific work, how many things he did by himself and how important were results he personally obtained. When he became a director of the Zavoisky Kazan Physical-Technical Institute (KPhTI) in Kazan, he impressed me very much as a talented and powerful administrator. Also, I recollect the hospitality he and his wife Zoya provided me and other guests from Novosibirsk when visiting his home in Kazan. So, I consider it as a good fortune for me that I have met this excellent person."

Kev Salikhov is one of the pioneers of spin chemistry, a branch of chemistry, which deals with the role of spins in chemistry, magnetic field effects on chemical reactions and chemically induced polarization of electron and nuclear spins. Kev's contribution to this field is widely recognized. He was one of the first to provide the correct interpretation for magnetic field effects and magnetic isotope effects

on chemical reactions and to develop a theoretical framework for spin chemistry. Notably, Kev Salikhov has also predicted features in the magnetic field dependence of reaction yield originating from level crossings in transient radical pairs (known as MARY lines), contributed to pioneering works on optically detected EPR of radical ion pairs (in cooperation with Y. N. Molin et al.) and proposed the stimulated nuclear polarization technique. Prof. Robert Kaptein says: "I have met Kev Salikhov during the late 70s and 80s in Novosibirsk, which was then (and still is) a place where Spin Chemistry is very actively pursued. I cherish fond memories of these encounters. I admired his strong theoretical knowledge and the many original ideas he had on CIDNP and the consequences of the Radical Pair Mechanism, such as magnetic field and isotope effects on chemical reactions. But I also remember with pleasure his lessons on fishing in the Ob lake and picking edible mushrooms! I congratulate him with his 80th birthday and wish him a long, productive, and healthy life."

After moving in 1988 to the Zavoisky Kazan Physical-Technical Institute (KPhTI) of the Kazan Scientific Center RAS as a director, Kev Salikhov stood active in the fields of EPR spectroscopy and spin chemistry. The Kazan period of Kev Salikhov was very fruitful from the scientific as well as from the administrative point of view. From 1988 to 2015 he was successfully supervising KPhTI as its director; presently, Kev Salikhov is a scientific supervisor of KPhTI. Since 1988, KPhTI has become one of the world leading centers in the field of radio-spectroscopy. The experimental facilities have been renewed and new directions of research were started at the institute: spin chemistry, EPR investigations of light harvesting by photo-synthetic systems, femtosecond spectroscopy, atomic force and scanning tunneling microscopy, quantum informatics and quantum information processing using spins. During the same time the department of chemical physics has been founded at KPhTI, which includes five modern, well-equipped laboratories, with active research using the techniques of magnetic resonance, femtosecond spectroscopy and scanning probe microscopy in the fields of molecular magnetism, fast chemical processes and quantum computing. Under supervision of Kev Salikhov, low-field MRI scanners have been developed, produced, certified and brought to hospitals. By Kev's initiative in 1998 the chair of Chemical Physics of the Kazan State University has been founded, based at KPhTI; in 2006 the dissertation council (for PhD and habilitation defenses) has been established with Kev Salikhov being its head.

Prof. Yuri Molin says: "In the late 80s an opportunity opened for Kev to head a leading physical-technical institute in Kazan. Being the director of ICKC at that moment, I chose not to talk him out of this move despite the great loss this certainly was for our institute. It was in Kazan that another dimension of his talent, the ability to organize major scientific projects, has fully developed."

Answering to the question "What was the main challenge when you moved to Kazan?" Kev Salikhov says: "Kazan is the Motherland of EPR spectroscopy. The EPR effect was first detected by Evgeny Zavoisky at Kazan State University. Zavoisky then became the co-founder of the Kazan Physical-Technical Institute of the Russian Academy of Sciences. So Kazan already had good traditions in studying the EPR phenomenon with very qualified experts in the field. The main challenge was to make the Zavoisky Institute the center of excellence of EPR spectroscopy."

As KPhTI director, Kev Salikhov has promoted an idea to establish an international scientific journal in Russia. This initiative has been successfully realized: since 1990 the journal "Applied Magnetic Resonance" is being published; all the time Kev Salikhov was its editor-in-chief. For many years, Kev Salikhov is the head of the international committee, which awards the International Zavoisky prize (initiated by him) for outstanding achievements in EPR development and applications in all fields of research. This prize has been supported by KPhTI, Kazan State University and Springer-Verlag, which cooperates with KPhTI publishing "Applied Magnetic Resonance". Presently, the Zavoisky prize is recognized by the AMPERE Society, International EPR/ESR Society, RAS Presidium and government of the Republic of Tatarstan; more than 30 scientists from the USA, UK, Germany, Switzerland, the Netherlands, Israel, Italy, Japan and Russia have become Zavoisky awardees.

Kev's activities have received high recognition. In 2007 he received the order of the Russian Federation "For merits to the Fatherland" (IV class). In 1998 he was awarded with the State Prize of the Republic of Tatarstan in science and technology. He also received the order "For merits to the Republic of Tatarstan". Kev Salikhov has become an honorary citizen of Kazan. Kev is active in the social and political life of the Republic of Tatarstan. In 1991 he has played an important role in establishing the Academy of Sciences of the Republic of Tatarstan. He has been one of the founding academicians and was its vice-president for many years. Kev Salikhov is a member of the President of Tatarstan committee awarding state prizes and a member of the main scientific editorial board of the Tatar Encyclopedia and a deputy editor of the atlas of the Republic of Tatarstan.

During these years, Kev Salikhov has made seminal contributions to pulsed EPR. Notably, he contributed to theoretical understanding of the so-called out-of-phase spin echo observed in spin-correlated radical pairs (SCRPs), developed (with Dietmar Stehlik et al.) the "observer spin" methodology in EPR and the theoretical framework for EPR spectroscopy of SCRPs in photosynthetic reaction centers, predicted unusual quantum beats in SCRPs, which can be probed by EPR methods, discovered a new feature in optically detected EPR spectra, and so on. In Kazan, Kev Salikhov also got interested in quantum information processing and proposed new protocols for performing quantum teleportation with the aid of SCRPs.

As his main scientific achievements Kev Salikhov mentions the following:

1. I have developed the theoretical tools to treat the spin dependent bimolecular processes: the recombination of free radicals, the spin exchange between paramagnetic particles, the mutual annihilation of two triplet excitons, etc. I have suggested proper kinetic equations for the one particle spin density matrixes including bimolecular collisions of paramagnetic particles in dilute solutions. These kinetic equations are the quantum analogues of the well-known Boltzmann kinetic equation for the one particle distribution function. The kinetic equations suggested allow one to calculate the rate constants (or cross-sections) of bimolecular spin processes in a condensed medium taking into account all re-encounters of a given pair of particles. Using these kinetic equations I succeeded in solving numerous problems concerning the magnetic effects in radical reactions, comprehensively developed the theory of the spin exchange – the spin coherence transfer induced by the exchange interaction.
2. I have formulated a new approach for describing the nuclear and electron spin polarization induced in a course of the spin dependent elementary chemical reactions, elementary photo-physical processes, electron-hole recombination in semiconductors, etc., known as chemically induced nuclear spins and electron spins polarization (CIDNP and CIDEP, respectively). This method is based on the idea that to calculate the spin polarization in situations indicated above the full information on the system is not necessary. It appears to be expedient to introduce new operators which describe the quantities measured in NMR and EPR experiments. These new operators obey the Heisenberg equations. Average values of their solution give the quantities observed experimentally: net polarization effect, multiplet polarization effect, etc. Using this approach one can easily find qualitative regularities of CIDNP and CIDEP effects.
3. I did several theoretical predictions which were later confirmed experimentally. Let me refer to just a few examples. It was predicted that in the presence of spin exchange the EPR lines can demonstrate a mixed shape, admixture of the absorption and the dispersion contributions. This observation was confirmed years later. Today there are efficient algorithms for determining the spin exchange rates based on the analysis of this mixed line shape. The theoretical prediction of the possible mutual effect of nuclear spins on CIDNP formation initiated numerous experiments. I was lucky to make nice observations concerning EPR of the charge separated states in the reaction center of the photosynthetic systems: the quantum beats of intensities of the EPR lines and the anomalous phase of the electron spin echo signals.

Kev Salikhov is a wonderful writer. To each of the fields where he was active he contributed not only by scientific papers but also by excellent monographs. These

are: “Electron Spin Echo and Its Applications” (with Anatoli Semenov and Yuri Tsvetkov), “Spin exchange” (with Kirill Zamaraev and Yuri Molin), “Spin Polarization and Magnetic Effect in Radical Reactions” (with Yuri Molin, Renad Sagdeev and Anatoli Buchachenko) and “Magnetic Isotope Effect in Radical Reactions”. Additionally, Kev was an editor of the book “Foundations of Modern EPR” (with Gareth Eaton and Sandra Eaton). These books are well known to the research communities in the respective fields. Kev Salikhov has been the founder and scientific editor of the international scientific educational publication “The Treasures Of Eureka”. Volume 1 titled “Electron Paramagnetic Resonance from Fundamental Research to Pioneering Applications & Zavoisky Award” was published in 2009.

Kev Salikhov has invested a great deal of his efforts and creativity into teaching in Novosibirsk (chair of Chemical Physics of the Novosibirsk State University) and in Kazan where he established the Chemical Physics Chair at the Kazan State University. He has also published several highly instructive books for students in Novosibirsk (together with Nikolai Bazhin) and the exciting “Ten Lectures on Spin Chemistry”. Kev has supervised 24 PhD theses and was an excellent teacher and guide to young talented people entering the exciting realm of chemical physics.

Answering the question “How did science change during the long time of your career?” Kev Salikhov says: “Over the last 50 years, science has changed extraordinarily. To illustrate this statement let me refer to just one example. In 1959 Richard Feynman presented a lecture titled “There’s Plenty of Room in the Bottom. Invitation to Enter a New Physics”. The lecture was about the possibility of atomic sized automotives and computers. He said: “I would like to discuss this, just for amusement”. That was like a dream back then. This year, Nobel Prize winners in Chemistry Jean-Pierre Sauvage, Bernard Feringa and Fraser Stoddart have designed and synthesized such molecular devices. There are many other examples of great changes in science over last 50 years where we are constantly creating past dreams of those before us, and dreaming our own dreams for future scientists.”

Salikhov’s scientific achievements are well recognized worldwide. Together with Yuri Molin, Renad Sagdeev, Anatoli Buchachenko and Evgeny Frankevich he has received the Lenin Prize in 1986 (the highest prize for science in the Soviet Union); in 1992 – fellowship of the Institute for Advanced Study in Berlin; in 1996 – the Gold Medal of the International EPR/ESR Society and the distinction of the Famous Scientists (from the RIKEN Research Center, Japan); in 2000 – the award of the Australian/New Zealand Society for Magnetic Resonance; in 2001 – the Award of the Alexander von Humboldt Foundation (Germany); in 2004 – the Zavoisky award (together with Dietmar Stehlik); in 2012 – the Bruker Prize; in 2014 – the Voevodsky Award. In 1997 Kev Salikhov has become a corresponding member and in 2011 full member of the of the Russian Academy of Science.

A few quick questions to Prof. Salikhov just before he gets 80:

Just before getting 80, what are your future plans? – I do not consider 80 years as something special; I plan to continue my scientific activity. I feel myself in creative form.

What gives you the inspiration to do science? – The search for scientific truth.

Which advice(s) would you give to young scientists? "Be courageous!"

As Laila Mosina, a close coworker and friend, says: "The free flight of Kev Salikhov's innovative thinking, his fantastic creativity, inexhaustible optimism and contagious enthusiasm evoke sincere admiration and inspire everyone, who is lucky to know Kev and to collaborate with him. You will never give him his age – concerning his creative potential, he is in the heyday of youth."

We wish Kev Salikhov to continue his research activities and to keep serving the magnetic resonance community: good health, prosperity and many more fruitful years in science!

Gerd Buntkowsky

Konstantin Ivanov

Hans-Martin Vieth

Dear Friend,
Dear Kev,
Dear Professor Kev Minullinovich Salikhov,

My hearty congratulations to your 80th birthday.
I am proud to have such a dear friend and a great scientist in Tatarstan State who has achieved global fame with your unmatched achievements in Electron Spin Resonance.
For me, your brilliance is like the glow of the Morning star that enlightens the science of Russia
and provides hope for more exiting and important achievements emerging into science from Russia and Tatarstan.
I hope that science can profit for a long time to come from your creativity and your friendship.
With my very best wishes to you and your family for a prosperous future in science,

Yours Richard R. Ernst

Prof. Dr. Richard R. Ernst
ETH Zürich
Laboratorium für Physikalische Chemie

Congratulations to the 80th Birthday of Professor Kev M. Salikhov

We are very much excited to contribute to the Special Issue of Zeitschrift für Physikalische Chemie in honor of Professor Kev M. Salikhov. It is a wonderful idea to publish such a special issue considering what Kev M. Salikhov has done for the EPR community through his enthusiastic and long term scientific activities. Let me point out some wonderful achievements he has done from the view point of International EPR(ESR) Society (IES) President.

Kev M. Salikhov initiated the International Zavoisky Award in 1991, which is to recognize truly outstanding applications or developments of EPR in any field of science. It is awarded every year in Kazan during the end of September, which is related to the birthday of Zavoisky who discovered EPR in 1943. Looking at the scientific level of award holders, it is no doubt that the International Zavoisky Award is internationally recognized as one of the major awards for scientific achievements. It is also recognized by the IES, the AMPERE Society and more.

The journal "Applied Magnetic Resonance" was also established under the initiative of Kev M. Salikhov since 1990. It provides an international forum for the application of magnetic resonance, including EPR, in various fields, and the editorial office is situated at Kazan. Thanks to Kev M. Salikhov, the conference contributions of the Asia-Pacific EPR/ESR Symposium (APES) which is organized every 2 years are published as a special issue of "Applied Magnetic Resonance" after the conference.

We feel that these activities are really pushing up the recognition of Kazan, the birth place of EPR by Zavoisky, and we are very happy to attend conferences in Kazan, such as the annual international conference "Modern Development of Magnetic Resonance". The tireless activities are promoting international collaborations and networks, and the community would like to express our gratitude to Kev M. Salikhov.

Kev M. Salikhov visited my group and Japan many times, for instance, APES2001 (Kobe), APES2014 (Nara), ISESS-SEST2007 (Shizuoka) and Kobe Workshop 2007. He is always very enthusiastic and willing to discuss with others about EPR science. I remember clearly that he was very happy to make his dream come true by seeing the Pacific Ocean and at the same time having intensive discussions about quantum computing at the Japanese style hot-spring in

Shizuoka. I am sure that Kev M. Salikhov will continue his enthusiastic science activities, and the EPR community will continue to benefit from them.

Kobe, Sept. 21, 2016

Hitoshi Ohta
IES President
Molecular Photoscience Research Center,
Kobe University, Kobe 657-8501, Japan

Kev Salikov's 80th Birthday: Small Interactions With Large Consequences

It is a distinct honor and great pleasure to address Kev M. Salikhov in this special issue of *Zeitschrift für Physikalische Chemie* dedicated to him on the occasion of his 80th birthday (November 3, 2016). This *Festschrift* continues the longstanding academic tradition of honoring scientists who have had a major impact on an important field. And Kev Salikhov is an outstanding example of such a distinction in the multi-facetted disciplines of magnetic resonance where he has left so many pathbreaking footsteps – and continues to do so.

From 1963 to mid 2016, Kev Salikhov has (co)authored more than 220 publications in premier scientific journals, and he published nine books. He laid the theoretical foundation for several advanced pulse EPR methods which are now commonly used. Kev Salikhov made key theoretical contributions to spin chemistry for an understanding of the magnetic field and magnetic isotope effects in chemical reactions, of the electron spin and chemical dynamics in complex liquid and solid systems, and of the electron- and nuclear-spin nonequilibrium hyperpolarization. He contributed strongly to the world-wide efforts to elucidate the potentials of pulse EPR methods for monitoring the spatial structure of paramagnetic pairs in disordered systems. More recently, his research interests have expanded to EPR imaging in medicine, to femtosecond spectroscopy and femtochemistry, to spin technology as well as to quantum computing and quantum informatics. For this he is using electron spins as qubits and spin-dependent elementary chemical acts as quantum logic operations.

In the following we briefly mention a few prominent examples of Kev Salikhov's research activities over the years: The determination of the structure of paramagnetic centers in disordered solids is an important issue. He is using the effect of electron spin-echo envelope modulation (ESEEM) to detect weak spin-spin interactions. While Larry Rowan, Erwin Hahn and Bill Mims were the first, in 1965, to observe and analyze ESEEM of paramagnetic centers in single crystals, Kev Salikhov pioneered, 3 years later in cooperation with his Novosibirsk colleague Georgy M. Zhidomirov, ESEEM of paramagnetic centers in disordered solids and frozen solutions. In 1968, they published their results in Russian, but it took several years until their work received the well-deserved appreciation by the EPR community in the West. In this paper, for the first time the concept of selective excitation of spins in disordered systems was introduced which is nowadays widely used in modern solid-state pulse EPR spectroscopy.

One of the main goals of pulse EPR spectroscopy from the very beginning was to measure the weak dipole-dipole interaction between paramagnetic centers or spin

labels in order to extract precise distance information. In the 1960s–1980s, Kev Salikhov as a theoretician has profoundly contributed to solving this problem. His studies of possible manifestations of the weak magnetic dipole-dipole interaction between localized spin labels have provided a basis for the now flowering applications of pulse electron double resonance (PELDOR) spectroscopy (or DEER, double electron-electron resonance). The paper "Application of the double resonance method in the electron spin echo to study spatial distribution of paramagnetic centers in solids" by A. D. Milov, K. M. Salikhov, and M. D. Tshirov, *Solid State Physics* (in Russian), **23**, 975 (1981), gave a start to numerous applications of PELDOR methodologies to study the structure of proteins, drugs, transition-metal complexes, biomolecules, etc.

Among Kev Salikhov's scientific "hot" topics is Photosynthesis, specifically the light-induced electron-transfer reactions in photosynthetic reaction centers (RCs). He made several fundamental contributions to the EPR spectroscopy of charge-separated radical-pair states of donor and acceptor cofactors in the electron-transfer chain of bacterial RCs. He theoretically predicted new spin phenomena, such as quantum beats of the EPR line intensity and out-of-phase spin echoes of spin-correlated radical pairs in RCs. These spin phenomena were experimentally observed in several laboratories shortly after they had been predicted. The out-of-phase spin echo detection of correlated radical pairs turned out to be extremely useful for characterizing short-lived reaction intermediates in natural and artificial photosynthesis and identifying their photo-reaction pathways. In cooperation with Dietmar Stehlik (Berlin) a novel strategy was developed to study the electron-transfer radical pairs in photosynthetic RCs by introducing an additional stable electron spin by site-directed spin labelling [K. M. Salikhov, A. van der Est, D. Stehlik, "The Transient EPR Spectra and Spin Dynamics of Coupled Three-Spin Systems in Photosynthetic Reaction Centres", *Appl. Magn. Reson.* **16**, 101 (1999)]. In later years of this collaboration, Kev Salikhov suggested a quantum-computer protocol for the quantum teleportation across a biological membrane in photosynthetic RCs [K. M. Salikhov, J. H. Golbeck, D. Stehlik, "Quantum Teleportation Across a Biological Membrane by Means of Correlated Spin Pair Dynamics in Photosynthetic Reaction Centers", *Appl. Magn. Reson.* **31**, 237 (2007)]. At the moment, several research groups in Russia, Germany, Canada, and USA work on the realization of this protocol.

In the 1990s, Kev Salikhov got interested in the promising field of EPR imaging. While NMR imaging became a well-developed method for medical diagnosis, EPR imaging is much less developed. An obvious problem is the skin effect of conducting substances or microwave (MW) absorption of lossy dielectrics when high-frequency MW fields are applied as in EPR. Kev Salikhov and his colleagues in Kazan established theoretically the algorithms of EPR imaging for conducting and lossy dielectric materials [M. P. Tseitliun, K. L. Aminov, K. M. Salikhov,

"Magnetic resonance spectrum of localized spins in conductive materials in linear field gradient", *Appl. Magn. Reson.* **16**, 325 (1999); K. L. Aminov, M. P. Tseitliun, K. M. Salikhov, "I-D EPR imaging of conducting and lossy-dielectric samples" *Appl. Magn. Reson.* **16**, 341 (1999)]. The idea is to record spectra under negative and positive magnetic field gradients to obtain a single complex projection. The obtained results can be applied to high-field NMR imaging as well.

Since the early years of 2000, Kev Salikhov got strongly involved in quantum computing. The miniaturization of computer units to the nanometer scale leads not only to much more memory space of computers. Even more important is that the quantum properties allow for performing certain computational tasks much more efficiently than any classical supercomputer will ever be able to do. Moreover, these quantum properties allow unprecedented tasks to be performed such as quantum teleportation, generating true random numbers, etc. Advanced pulse EPR methods are promising to provide the necessary tools to manipulate the states of electron spins in molecular systems according to algorithms of quantum computing. Kev Salikhov suggested protocols, based on the pulse EPR methodology, to use electron spins as qubits for quantum computing and quantum informatics, providing the basic logic operators Not (NOT) and Controlled Not (CNOT). CNOT is a 2-qubits (2-spins) operation and, in order to perform the logic operation, the two spins should interact. But only weakly, of course, to retain long enough spin-decoherence (phase-relaxation) time for controlled spin manipulation by MW pulses. Together with his student Michael Volkov, Kev Salikhov solved this problem [M. Yu. Volkov, K. M. Salikhov, "Pulse protocols for quantum computing with electron spins as qubits", *Appl. Magn. Reson.* **41**, 145 (2011)]. It turned out that the CNOT protocol needs more than 20 microwave pulses. This means that the realization of the CNOT logic operation with electron spins as qubits needs about 200 ns. Thus, the electron spins should possess phase-relaxation times longer than 1 μs needed to apply the necessary pulses to manipulate the electron spin states. Such requirements can probably be fulfilled and, indeed, quite a number of research groups are trying to realize a quantum computer with electron spins as qubits.

Since the early stages of his academic career, i.e. in the early 1960s and 70's when working on his first and second doctorate in physical-mathematical sciences, Kev Salikhov made major contributions to the theoretical description of bimolecular collisions and spin exchange between paramagnetic species in diluted solutions. Spin exchange is an ongoing theme for him since then. In 2014, for example, Kev Salikhov published together with colleagues extensive studies of spin exchange in electrolytes between charged particles. Most recently, in August 2016, Kev Salikhov published a keynote paper in which he developed the theoretical tools to comprehensively analyze the manifestations of spin-exchange and

coherence-transfer processes in the EPR spectra [K. M. Salikhov, "Consistent Paradigm of the Spectra Decomposition into Independent Resonance Lines", *Appl. Magn. Reson.* **47** (2016), DOI: 10.1007/s00723-016-0823-3]. The shapes of the spin resonance spectra in the presence of coherence transfer have been analyzed theoretically. A consistent approach is described for the decomposition of the multicomponent spectra into individual resonance lines which is based on finding independent collective modes for the evolution of quantum coherences. In the presence of the coherence transfer, the shapes of resonance lines corresponding to these modes can be a mixture of Lorentzian absorption and dispersion curves. In the limit of fast coherence transfer – corresponding to the exchange narrowing effect – one collective mode gives the dominant contribution to the experimental spectrum. The theoretical results obtained have created a solid base for applications of weak spin-spin interactions between spin probes as a powerful analytical tool in reaction chemistry and molecular biology.

Before concluding this section on Kev Salikhov's wide-ranging research interests, his fundamental contributions to the fascinating field of Spin Chemistry should not go unmentioned [see the book classic: K. M. Salikhov, Yu. N. Molin, R. Z. Sagdeev, A. L. Buchachenko, *Spin Polarization and Magnetic Effects in Radical Reactions*, Elsevier Amsterdam (1984)]. He made a strong impact on the theory of CIDNP and CIDEP phenomena. He determined the maximal possible contribution of the electron-nuclear hyperfine interaction with magnetic nuclei to the recombination rate of free radicals. The maximal radical-pair recombination probabilities upon substitution of magnetic isotopes for non-magnetic nuclei have been found on the basis of the total spin conservation of the unpaired electrons and magnetic nuclei in a radical pair. Kev Salikhov predicted and, together with colleagues, developed the first theory of the stimulated nuclear spin polarization (SNP) effect in high magnetic fields [K. M. Salikhov, S. A. Mikhailov, M. Plato, *Chem. Phys.* **117**, 197 (1987)]. The SNP effect is being used as a highly sensitive new method to detect the EPR lines of short-living radical pairs. Finally, in 2004, Kev Salikhov suggested a new mechanism of excited triplet states electron spin polarization caused by the mutual annihilation of triplet states, which was soon (2005) experimentally confirmed. This triplet spin hyperpolarization has a perspective to be used in spintronics devices.

Considering his fundamental contributions in such a wide-spread research area as Kev Salikhov's, it is not surprising that his list of Honors and Awards is impressively long:

2015 Fellow of the International Society of Magnetic Resonance (ISMAR)
2014 Fellow of the International EPR/ESR Society (IES)

2014	International Voevodsky Award
2012	Bruker Prize of the UK Royal Society of Chemistry
2011	Honorary Citizen of Kazan
2007	Russian Federation State Order of the IV degree
2006	Tatarstan Republic Order for service to the Republic of Tatarstan
2004	International Zavoisky Award
2000	Lecturer Award of Australia & New Zealand Magnetic Resonance Society
2001	Alexander-von-Humboldt-Foundation Fellowship Award
1998	State Prize of the Republic of Tatarstan
1996	"Eminent Scientist" Prize of the RIKEN Institute, Japan
1996	Gold Medal of the International EPR/ESR Society (IES)
1992	Fellow of the Wissenschaftskolleg in Berlin (academic year 1992/93)
1986	Lenin Prize (Science and Technology)

Kev Salikhov's service and contributions to the international scientific community are exemplary. A selection thereof comprises:

2015	Co-organizer of the second international conference "Spin physics, spin chemistry, and spin technology" in St. Petersburg, Russian Federation
2011	Founder and organizer of the first international conference "Spin physics, spin chemistry, and spin technology" in Kazan, Tatarstan, Russian Federation
1994	Organizer of the 27th AMPERE Congress in Kazan, Russian Federation
Since 1992	AMPERE Committee member
Since 1991	Chairman of the International Zavoisky Award Committee
1990	Initiator of establishment of the International Zavoisky Award to recognize outstanding applications or developments of EPR in any field of science
Since 1990	Founder and Editor-in-chief of the journal *Applied Magnetic Resonance* published by Springer, Wien
Since 1989	Organizer of the annual international conference in Kazan "Modern Development of Magnetic Resonance"
1989–2001	Board member of the journal "Khimicheskaya fisika" (Russian Journal on Physical Chemistry)

A short abstract of Kev Salikhov's professional experience and scientific career is appropriate:

Present status Scientific Leader of Zavoisky Physical-Technical Institute of the Russian Academy of Sciences, Kazan, Tatarstan, Russian Federation

1988–2015	Director of Zavoisky Physical-Technical Institute of the Russian Academy of Sciences, Kazan, Tatarstan, Russian Federation
Since 2011	Academician (Full Member) of the Russian Academy of Sciences, Russian Federation
Since 1997	Correspondent Member of the Russian Academy of Sciences, Russian Federation
Since 1992	Academician (Full Member) and Vice-President of the Academy of Sciences of Tatarstan, Russian Federation
Since 1989	Full Professor in Chemical Physics at Kazan State University (now Federal University), Kazan, Tatarstan, Russian Federation
Since 1989	Head of the Chemical Physics Department of the Zavoisky Physical-Technical Institute of the Russian Academy of Sciences, Kazan, Russian Federation
Since 1980	Invited researcher in leading EPR laboratories including the Free University Berlin, Germany, in the groups of D. Stehlik and K. Möbius; the Institute of Physical and Chemical Research (RIKEN), Japan, in the group of H. Hayashi; the Cornell University, USA, in the group of J.H. Freed
1979–1988	Full Professor in Theoretical Physics at Novosibirsk State University, Novosibirsk, USSR
1967–1979	Associate Professor at Novosibirsk State University, Novosibirsk, USSR
1963–1988	From Junior Researcher to Researcher to Senior Researcher and since 1986 Key Scientific Researcher at the Institute of Chemical Kinetics and Combustion of the Siberian Branch of the USSR Academy of Sciences, Novosibirsk, USSR
1974	Doctor of physical-mathematical sciences, defended at Kazan State University, USSR, reviewers: S.A. Altshuler, G.R. Khutsishvili, V.A. Atsarkin, B.N. Provotorov, B.I. Kochelaev
1962–1963	Assistant Professor at Karaganda Polytechnical University, Kazakhstan, USSR
1959–1962	Research and Ph.D. (1963) with M.V. Volkenstein and Yu.Ya. Gotlib, Institute of High-molecular Compounds of the USSR Academy of Sciences, Leningrad, USSR

In summary I would like to emphasize:

The characteristic feature of the creative activity of Kev Salikhov is his close interaction with experimenters throughout the world. Communication and cooperation are the key ingredients for his scientific success and personal happiness. The theoretical predictions made by him were practically all confirmed in experiments in many laboratories. Quite often they stimulated new experiments and applications. A peculiar advantage of pulse EPR spectroscopy is that it reveals extremely weak magnetic interactions, such as the hyperfine interaction of electron spins with magnetic nuclei or the dipole-dipole spin-spin interaction between spin labels. These interactions might be million times less than the thermal energy kT at room temperature. Nevertheless, they have large consequences in chemistry and biology at large. For instance, in controlling essential pathways of chemical electron-transfer reactions after their photo-initiation.

Kev, your work has stimulated the scientific thinking of many colleagues, partners and friends in the world-wide magnetic resonance community. Kev, we wish you and your family the very best for many more years to come. Kev, we look forward to your continued contributions to science and friendship. Kev, over the years your friendship has enriched our life. Thank you!

Klaus Möbius
Free University Berlin & Max Planck Institute for Chemical Energy Conversion

Greetings to Kev Salikhov on his 80th Birthday

Dear Kev,

Warmest congratulations to your 80th birthday. I enormously enjoyed participating in the celebration in Kazan on that day. Memories came back about the XXVII Congress Ampere, Kazan, August 21–28, 1994 celebrating the 50th anniversary of the discovery of EPR by Eugene Zavoisky. I recall the heavy discussions in the Bureau of the Groupement AMPERE in Zürich, where you promised to solve all problems that members of the Bureau brought up. It was a difficult time after the collapse of the Soviet Union, but with your help a charter flight from Frankfurt to Kazan was organized, which brought more than 100 participants from Western countries to this event. Together with those who made their own travel arrangements more than 150 colleagues from Western countries came to Kazan, and this fact made a marked impression on the Tatarstan government, the President himself opened the Congress.

This little story should remind us on what we all admire so much about you. Your enthusiasm for your research and the world wide community of scientists is unprecedented. You made the E. K. Zavoisky Physical-Technical Institute in Kazan a worldwide recognized center of EPR spectroscopy and its members spread around the globe.

You are still full of ideas and I wish you continuing good health such that you can realize them both in science and with your large family.

Best Wishes,
Hans Wolfgang Spiess
Max-Planck-Institute for Polymer Research, P. O. Box 3148, D-55021 Mainz, Germany