Preface

HISTORICAL OVERVIEW

The 20th century will be remembered for the rate of expansion of knowledge about Nature and the Physical World that was faster than at any other time in the history of human civilization. One could argue about the factors that contributed to this revolution but perhaps the most important was that the foundations of physics and the development of the methods of scientific reasoning were already laid down. This was the achievement of the pioneers of science following the 16th century whose monumental contribution was the construction of the basic rules of physics. They not only discovered the fundamental laws of Nature but more importantly they developed the methods of scientific reasoning. By the end of the 19th century mechanics of particles was completed, gravity was thought to have been understood and electromagnetism was formulated in a logically closed form (historical account of that period in science was detailed by [Whittaker (1953)]). The triumph of the latter was in discovery of electromagnetic waves by Hertz in 1888. There were signs of certain flaws, for example it was known that gravity does not give precise answer to the motion of planets, unification of dynamics for the electromagnetic field and charged particles was hampered by curious non physical results and radiation law for black body at certain temperature could not have been solved completely (*clouds on horizon* as Kelvin described them in 1900). There were certain baffling phenomena that could not be explained by anything that was known at the time, such as where the Sun gets its energy (a plausible answer was proposed by Helmholtz in 1854 and later improved on it and criticized by Kelvin in 1861). Despite these open questions physics was thought to have been a closed subject, in particular mechanics of particles, but what was forgotten is that there were relatively few very precise confirmations of its validity. One reason is that experimental methods were not sufficiently accurate, and also relatively few phenomena were at disposal that can be used for tests. Prediction of motion of planets was one, and the agreement with the observation was such that there was no doubt that mechanics based on the Newton's laws was valid. Furthermore these laws were in accord with at that time prevailing philosophy of determinism: given initial conditions one could predict the fate of any system. This happy union between philosophy and physics prevented observation that could have been made even at that time, because mathematics was developed sufficiently to describe it as a general law and also relatively simple experiments could have confirmed it. This observation is that the basic laws of dynamics cannot be deterministic, because no matter how small an error in determining initial conditions is made given sufficiently long time it can increase to almost any value (general mathematical proof for non–linear differential equations was given by Lyapunov in 1892 and in 1908 it was applied to physical problems by Poincare). Based on this observation the emphases in the laws of dynamics could have changed from the concept of trajectory, which epitomizes certainty, to the concept of probability, which epitomizes uncertainty.

It is no wonder that it was a matter of time before the laws of physics of that time were put to far more stringent tests. However, that came from the direction that at first glimpse did not have much relevance to dynamics of particles: from the radiation experiments. Puzzling discrete spectral lines of atoms and molecules needed explanation but it was thought that a suitable model of atom would explain it, within classical laws of physics. However, it was the black body radiation law that defied all attempts of explanation, which was eventually done in 1900 by Planck but it needed a very bold assumption. It was essentially a one parameter mathematical fit, but it was derived from a physical principle: exchange of energy between matter and radiation field goes in discrete lumps rather than in a continuous way. The principle defied everything that was known about electromagnetic interaction with charges, but the result gave an excellent agreement between experiment and theory. Furthermore the assumed parameter had universal value, i.e. once experimentally determined it could fit the radiation law for any temperature of the black body. The parameter is known today as the Planck constant. Looking back on that development the physical principle that Planck introduced was the turning point in modern physics, not only in practical terms but also in the spirit. The major advances, and also the conceptual framework, were built around the radiation problems, while mechanics of particles became secondary to that. That became evident soon when the rotational spectra of molecules ([Bjerrum (1912)]) were successfully described by using the Planck's principle. This was achieved without making reference to mechanics of rigid rotors; the only premise was the Planck assumption about the properties of radiation.

Although the Planck's principle was a breakthrough at the time, it was still too early to talk about its serious implications for the foundations of physics. It was another event that was the true challenge to them, painstakingly laid over a few centuries. It came with the discovery by Lenard in 1902 that energy transfer from the electromagnetic field to matter (more specifically to the electron) depends on the frequency of the former and not its intensity (the photoelectric effect). The effect itself is important because it urges the need for better understanding of radiation–matter interaction, but in addition to that it resulted in another important discovery: the free parameter h that Planck introduced to get the correct black body radiation law is the same as the constant that measures the energy exchange in the photoelectric effect. This discovery was the crucial turning point in several respects, and one could easily say, it determined the direction of physics in the 20th century. The fundamental dilemma, from today's perspective, with which the photoelectric effect confronted the science, was whether it is an indication of the character of mechanics of a charged particle or it reflects the character of electromagnetic field. There were no hints at that time that the principles of mechanics of particle should be modified, it was still too early for this action, and the choice was on the electromagnetic field. In support of this view was the Planck's principle, on the basis of which Einstein in 1905 gave the rationale for the experimental evidence. This choice was the watershed that set the course for the subsequent events because the spirit of physics changed: from being essentially mechanics of particles to being radiation physics. One supporting argument for such development was that the source of knowledge about dynamics of atoms was almost entirely spectroscopy while experiments with individual particles (mechanics) were few and not very accurate. However, one experiment of this kind, in which atoms (ions) were used, was the key to unveil the basic structure of atoms. In fact it was not structure that was unveiled but how the protons and electrons are distributed in the atoms. The importance of this discovery was also that it reconfirmed the validity of the mechanics principles because without such assumption Rutherford in 1911 could not have interpreted the data.

Discovering how the protons and the electrons are distributed in atoms was the basis for "attack" on the principal concern of scientists, their spectra, and among them the most elemental, that of the Hydrogen atom. The most obvious assumption was that the electrons move in orbits such as planets. There were a number of serious problems with such a model, one of them being how to choose those orbits that correspond to the observed spectral lines. By this time the Planck's principle was successfully implemented in various examples, and it was obvious that it should be applied to atomic orbital. But this was not the only problem to solve, in fact there were a number of others, more serious ones, that needed attention. Being aware of them, Bohr suggested nine rules that must be accepted before attempting to explain the spectra of atoms, and more generally, to describe the world of atoms (a good account of the rules was given by [Whittaker (1953)] pg. II/109). One of them, more precisely the last, set the scenery for all future events and the premise on which modern physics is based. It essentially says, "All visualization or classical explanation of behavior of the electrons must be dismissed". What the rules said was that in establishing new models it is allowed to ignore the traditional laws of physics, e.g. the radiation reaction force, as long as the results agree with observations. The Bohr's model of Hydrogen atom was very successful, but the irony is that it was not rejected because it violated traditional physical laws but because it could not reproduce the spectrum of the He atom.

Despite the excitement that was caused by those findings there was one important problem unsolved, formulation of the radiation reaction interaction. Its significance was established from the moment Maxwell equations were published in 1873 because without its solution two major dynamics, one for particles (charges) and the other for electromagnetic field, could not be unified. As a consequence, it is easily proved, the energy conservation law is violated. The initial attempt at its formulation was by Heaviside in 1902 and later developments were hampered by (a) the equations could not have been solved and (b) the source of it was not very clear. In the course of events the interest for the force diminished, and even today, when there is sufficient knowledge to be better understood, there is not much interest for it mainly because the attitude towards traditional principles of mechanics of charges and electromagnetic field changed – in modern physics they are in the archives of history. The problem, however, still remains, as one of the most fundamental in physics precisely because of its central role in the unification of two dynamics. The argument of modern physics is that the unification problem is solved within *quantum field theory*.

Formally, the spectrum of the Hydrogen atom could be calculated – in excellent agreement with the experiment – but the question remained as to why only certain electron orbits were (apparently) stable and all others were not. This is a concept totally alien to classical experience and defied some of its basic laws. It is at this point – perhaps more clearly than at any other time since Planck – a new element in science was introduced – pragmatism. A model that describes the world of atoms, even being in confrontation with the traditional physics, is acceptable as long as the results agree with the observations. The supporting argument for this is that the traditional experience obviously does not apply there and therefore it should be dismissed a priory. This pragmatism was behind the dawn of new idea that will be the basis for the new approach to the description of the world of atoms. Its main premise is that the traditional concepts are based on the elements that cannot be observed, such as trajectory of a particle; therefore one should try to understand dynamics of the quantities that are observed, called observables. Two of these are the spectral lines and the transition probabilities between the states from which radiation occurs. By assuming this line of approach one avoids using the tools of traditional physics, because there is no place in it to answer these new questions. On the other hand one works directly with the quantities that are verifiable. However, that also meant that new physical laws are gauged primarily to deal with spectroscopy rather than dynamics of particles, the spirit that prevails even today in modern physics.

The scene was set for the major breakthrough in modern physics: establishment of new theory, appropriately named *quantum mechanics (theory)* that would describe the world of atoms. All the ingredients were there, however, the way they are interconnected was rather confusing. Contribution towards this confusion was discovery that electrons should have additional property. It was associated with some sort of its internal rotational degree of freedom, and the closest analogy that could have thought of is the spinning sphere, therefore the name *spin* was given to it by Compton in 1921 (historic account of spin was given by [Tomonaga (1997)]). The property defied all attempts of traditional explanation, and the view was taken that this is an additional confirmation of the Bohr's ninth rule.

By this time there were several attempts to formulate the theory that would involve only the observables, among them being transition probability. The choice of this observable was motivated by the assumption made by Planck, and later employed in the description of the photoelectric effect, that radiation occurs in bundles of energy and therefore atoms cannot radiate in continuous manner. However, that means that radiation is (a) instantaneous and (b) within the lifetime of excited state there is no telling when this occurs. Only the probability of the event is observed. Irrefutable confirmation that radiation is an ensemble of these bundles of energy was confirmed by Compton in 1923 in the coincidence experiment, in which the recoiled electrons upon the impact of radiation goes in precisely defined angle if the recoiled radiation is observed at a given angle. The explanation was sought in the same spirit as the photoelectric effect: it is an indication of the character of the radiation field and not the character of mechanics of the electron. Based on this choice the outcome of the experiment was taken as the proof that in fact those bundles of radiation energy are nothing but manifestation of the particle nature of radiation (historical account is given by [Pais (1986)]). What was left unsolved is how to reconcile this picture with that of the definite indications that radiation also manifests wave like features. The pragmatism prevailed: the dualistic nature of radiation was accepted, and the explanation was that in the world of atoms the traditional views are anyhow abandoned and therefore this dualism cannot be understood with that experience.

It was as a consequence of these developments that the concepts of macroscopic and microscopic physics arose. Traditional physics could not be dismissed because it works well in the macroscopic regime, few would argue otherwise. However, the new physics was indispensable for the microscopic world. This separation was a deathblow for traditional approaches to the description of microscopic phenomena and it has all but disappeared from view during the advances of physics in the remaining part of the 20th century. That separation had deep consequences on the development of physics because by abandoning traditional views completely the view was taken that in microphysics everything is allowed as long as the results agree with the experiment. It held that no recourse to the traditional physical concepts was necessary or of value, and by abandoning this last important aspect of scientific method the abstract mathematical language took the leading role in advancing physics.

In the events that followed, the establishment of pre-eminence of the role of mathematics as the spearhead of research in physics came from two directions. One direction was the requirement of a compromise between two physically acceptable but conceptually exclusive phenomena, that of a wave-like and particle–like nature of light. For light, let alone for particles, the acceptance of this dualism was essentially a heresy, because the history of physics witnessed various arguments that tried to exclude one interpretation from the other. The dualism also meant breaking away from standard principles of logic, which are based on the “certainty” of arguments and not their fussiness. However, as soon as it was clear that mathematical methods were shown to describe experimental evidence very accurately, pragmatism prevailed and the "common" sense was forsaken. Instead of asking the question: *Why such models, based on arguments that violate the rules of "common" logic work?*, the line was taken that classical concepts were irrelevant. Much effort was expended in justifying dualism with the aim of replacing the traditional views by entirely new ones, and the all conquering argument was that agreement with the experiment was a necessary and sufficient requirement.

Further developments of physics were more or less predetermined, at least in the aspect of a general approach to the microscopic world. That meant modelling which is based on mathematical reasoning and not on physical intuition, which is best illustrated on development of a more elaborate theory, the quantum field theory. That very little what was left of contact with the traditional perception of Nature was eliminated, e.g. in replacing the electromagnetic field with operators. Replacing the wave functions by operators also severed the connection with quantum theory. The quantum field theory is therefore truly new theory without any connection with the classical world.

One event that followed the establishment of new foundations of physics was of great importance, and although it was recognized as such its far–reaching consequences were not fully utilized. By trying to give physical meaning to the newly born ideas Heisenberg derived in 1927, what is known today as, the uncertainty principle. It is essentially saying that simultaneous measurement of coordinate and momentum of particle is not possible with absolute accuracy, i.e. the product of their standard deviations is always greater than certain constant, which it turns out to be the Planck's. Importance of this finding is unquestionable but its full impact is overshadowed by the belief that it is derived from the more fundamental principles, such as the wave–particle dualism. In short, from the principles from which quantum theory is derived. Therefore according to this view the uncertainty principle cannot be taken out of the context of quantum theory, because there are more basic principles that set the theory apart from the traditional physics. This means it is meaningless to talk about the impact of the principle on traditional views because comparison is between the principles of wave–particle dualism, or observable–operator relationship, and the concept of trajectory. However, if the law of uncertainty (it should be called the law because it is derived from the principles of quantum theory) is put into the context of traditional physics then it is obvious what is missing in it. The principles of traditional physics are not wrong but their emphasis is put differently, it is on predicting the certainty of events and not their probability. The aspect of probability in traditional physics was unduly omitted from considerations, and one can argue about the reasons why is that so. Perhaps because there was really no necessity to introduce probability, not until the 20th century when the means of accurate measurements were available. The aspect of certainty also perpetuated the happy belief in the deterministic world and the power of logic that is based on it. It is curious, however, that in all history of physics the concept of probability in analyzing dynamics of particles and fields was never taken seriously, despite the fact that any experiment must be done under the assumption that the means of accurate measurements are limited.

PRINCIPAL AIM

The principal aim of the book is to give a unified treatment of two major descriptions of dynamics of particles: classical and quantum mechanics. Although they are both gauged towards the same goal, to describe dynamics of particles if their interactions are known, they have very little in common. Both are without questions valid in their own domain of applicability, but the rules that distinguish these are still the source of much discussion and controversy. The ideal resolution to that would be to have a unique set of postulates that encompass both descriptions, and there are at least two reasons to search for them. One is that of a fundamental interest because the physical principles that govern the processes in Nature should be unique, there cannot be a set of principles for one domain and the other principles in another. The most plausible premise would be assumption that quantum mechanics is fundamental description, which has its own set of postulates, and at the other end are the laws of classical mechanics that are derived from them. The recipe how is this achieved is still a mystery, but a very often used premise is that the "quantum rules" go over to the "classical ones" when the Planck constant "goes to zero" (whatever that means). There are various arguments in support of this premise, but the fact remains that in practice when this limit is implemented the result is seldom satisfactory. The unsuccessful search so far for this connection is perhaps an indication that the foundations of quantum mechanics may not be the correct ones, and that an alternative formulation of dynamics of particles is required, the one that is based on unification of the two dynamics rather than assuming that one (classical) is derivable from the other (quantum).

The other reason for studying unification of two dynamics is of a practical nature. In the applications quantum mechanics is often limited by the structure of its basic equations, which are partial differential equations and must be solved as both the boundary and the initial value problem. On the other hand in classical mechanics one solves ordinary differential equations, or the initial value problem only. This aspect of classical mechanics is great simplification over quantum mechanics, and unification of the two dynamics would make it possible to use that advantage.

The principal aim of the book is realized by formulating dynamics of particles from the three Newton postulates and two additional ones. One of them postulates a symmetry between the inertial reference frames, more specifically that no experiment can determine their absolute motion. The result is unification of space and time, better known as the *theory of relativity.* The other postulate states that even in principle it is not possible to perform simultaneous measurement of position and velocity (momentum) of a particle with absolute accuracy, which is known as the *uncertainty principle.* These five postulates should be sufficient to describe dynamics of particles, in particular classical mechanics (three Newton postulates), relativistic dynamics (fourth postulate) and quantum mechanics (fifth postulate). The fifth postulate is particularly important because in traditional approach quantum theory is derived from either the principle of dualism or the observable–operator substitute. It is shown in this book that these principles are derived from the postulate of uncertainty.

Implementation of new postulates is not possible without making fundamental changes in the basic premises of the Newtonian dynamics. For example, to apply the fourth postulate one must renounce the deeply inherent belief that space and time are independent variables, the assumption that is basic to the traditional classical mechanics. Without this change the postulate cannot be implemented. In the same way the deterministic basis of Newtonian dynamics should be abandoned in order that the fifth postulate could be applied, but this change is perhaps more drastic than the previous one. Namely, the deterministic view of the world was not only important to physicists, but it was also, and it still is, a central point of some of the major philosophical movements. Therefore abandoning such a view must accompany a change of attitude towards the question that is basic to human experience: what is the outcome of events if its initial conditions are known? The fifth postulate states that uncertainty is the basis of dynamics, which means that the question is meaningless and therefore

Newtonian mechanics should be formulated by emphasizing indeterminism rather than determinism. In other words, instead of the question being about precise fate of a particle if its initial conditions and forces are known it should be about the time evolution of probability for its whereabouts in the phase space (collective name for the position and momentum of particle). Once this change is made then implementation of the fifth postulate is a simple next step: of all the probabilities that describe dynamics of a particle one selects those that obey this postulate.

To achieve the goal of unifying dynamics of particle on the bases of those five postulates Newtonian mechanics must be first reformulated. This is the object of Chapters 1 to 5, in which the principal ingredients of Newtonian dynamics are retained but the emphases is changed from the particle trajectories to phase space probabilities. In this way the basis for implementing the fifth postulated is established.

Chapters 6 to 10 have the objective of implementing the fourth postulate on dynamics of particles, specifically in the context of reformulation of Newtonian dynamics in terms of phase space probabilities. The concept of field is introduced, and within this the essence of dynamics of the electromagnetic field is reviewed. Dynamics of the particle and that of the electromagnetic field are unified by deriving the field reaction force. Non uniformly moving reference frames are discussed, which has two objectives: one is to discuss the symmetry between the concept of force and that of accelerated coordinate systems, and the other is to review the basics of the force of gravity.

In Chapters 11 to 19 the postulate of uncertainty is introduced into the dynamics of a particle. It is shown that this is a sufficient criterion to derive the rules of quantum mechanics, for a general potential. In this way one avoids the traditional approach to quantum mechanics from the derivation of the black body radiation law, and later the wave–particle dualism. The theory is applied to various simple and less simple problems, with the emphases, where possible, on the use of the phase space dynamics. The use of some traditional concepts such as the transition probability, momentum operator, Hamiltonian, etc. are avoided as much as possible because the spirit of the approach changed from that of the spectroscopy to that of the dynamics of particle. Also the name "wave function" is avoided not as a disrespect for historical source of this name (its source is traced to the concept of the wave–particle dualism), but to emphasize the connection of this function with the concept of probability, hence the name "probability amplitude" is used instead. Furthermore the concept of a “plane wave” is used only as a mathematical object but no physical content is attached.

Many illustrative examples from individual chapters and subsections are found in the attached CD-Rom that goes with the book. A number of items that cannot be found in the book proper (e.g. Hydrogen atom) are referenced in the index file on the CD-Rom. These items are linked to a particular example where they are discussed. The examples are given in the format that uses the Adobe Acrobat Reader.

The book is the summary of my research in the atomic and molecular physics, more specifically in the area of collisions of atoms and molecules, and their interactions with the electromagnetic field. I had the privilege to be in the field from the (relatively) early beginnings, when there were problems to be solved but there were limited means, either in terms of hardware (computers) or the theoretical methods. There were two kind of problems, one was to calculate “numbers” that could be compared with experiments and the other was interpretation of results. In the calculation of “numbers” the theoretical basis was known, it was quantum theory, but neither the numerical methods were developed to solve its (partial differential) equations nor sufficiently powerful computing devices were available to implement these methods. Pragmatism prevailed and one resorted to classical mechanics to at least get some “numbers” and obtain insight into dynamics of molecular collisions, despite the fact that the prevailing philosophy was that its use is not legitimate. Pragmatism was based on the argument that solving classical equations is much easier, and even with those computing machines it was possible to solve them for a relatively complex systems. Another argument in support of using classical mechanics was that molecules are “almost classical objects”, whatever that meant. One big drawback with classical mechanics was that there were no rules to follow to obtain the results that make sense. There were few obvious ones, such as the Bohr quantization rule and to some degree the Ehrnfest theorem. A step forward was made by implementation of the path integral method of Feynman, but as a rule for none of the various approaches one would be confident to give reliable result. The usual answer was that “classical mechanics is not relevant anyway” and so discrepancy was expected as a natural consequence of disobeying the rule that quantum mechanics should be used. That is why classical mechanics was implemented in many different ways, because there were no first principles from which one would select the correct one. The “goodness” of a model was judged a–posteriori, by comparing its results with quantum calculations.

There was another feature of classical mechanics that made it attractive in applications, relatively simple interpretation of results. Namely, a rapidly evolving field of crossed molecular beam experiments provided data from which the atomic and molecular interactions could be deduced. The straightforward procedure to do that is by the "trial–and–error" method, i.e. to assume a sufficiently general potential with the adjustable parameters, calculate the cross sections and from the comparison with the experimental results optimize their values. This is a tedious procedure, and therefore a certain initial guess of the values of the parameters would be of great help. The most obvious way to achieve this is to find a relationship between certain typical features of the cross sections and those of the potential. The connection between these two features is not easily deduced from quantum mechanics, but from classical this is possible, which made it very attractive for applications. Here, again, the often encountered problem was how to interpret quantum mechanics in order that classical could be correctly implemented. In seeking the answer to this problem it gradually became obvious that central to it is the Heisenberg's law of uncertainty, which had been unduly neglected as the basic principle of Nature.

The idea that the uncertainty principle plays the central role in formulating quantum mechanics is not new, and the first attempts were made by Heisenberg but without success.[1] Few attempts at a later time by some authors were of a very superficial nature. In rediscovering this idea several obstacles had to be overcome, and the most difficult one was to convince myself that the idea makes sense. Many tests and inspections of various problems were undertaken, and many colleagues and friends were involved in discussion of them. They had many objections, from very simple ones, such as "what is the purpose of this, we know that quantum mechanics as it is gives good results", to the comments that it is an alternative Wigner function approach or it is nothing but manifestation of the Ehrenfest theorem. The suggestion was even that the Bohm‘s dynamics is better alternative to the one based on the premises that I was suggesting. My experience is that many of the discussion partners were virtually impossible to convince into the originality of the arguments, and my conclusion is now that in science it is often a matter of someone taste for the starting premises rather than objectivity of the arguments. I am afraid that such an observation also

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[1] Proper reference to this work was never found, this citation is based on the comments made by a number of scientists who had contact with Heisenberg.

applies to me, and therefore my only answer was to work out many examples from ordinary non relativistic theory to relativistic, to discuss some truly quantum effects from the classical point of view, e.g. spin and photons, and also try to solve the great remaining unsolved problem of the field reaction force and how is it combined with quantum theory. Most of this examples are analyzed here, and it is up to the reader to decide on their merits.

The actual work on the book started during my visit in 1998 to the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil. The visit was generously supported by FAPEMIG, and that included giving a course on dynamics of atoms and molecules. That was the opportunity to work parallel on the book and “testing” the ideas on students, but on the real problems of this dynamics. In this respect I am very thankful to Prof. J. Belchior for inviting me and for discussing the ideas, and then consenting on the course. The foundations of the book were laid and given an initial boost from the feedback from students, in particular N.H.T. Lemes, BSc. Great thanks also goes to Prof. J. P. Braga, from the same university, for many detailed discussions on particular subjects, and to Prof. A. Pinheiro and Mr. R. Diniz that made my stay a great experience. That was beginning, a very important one, but the road followed, a long and winding. I should thank Profs. M. Martinis, G. Pichler, N. Trinajstić and T. Živković, Drs. N. Došlić, T. Šmuc and I. Ljubić (BSc) in Zagreb for many discussions on what was sometimes a very esoteric subject in physics. Another great thanks goes to Prof. J. N. Murrell for a long time collaboration and from whom I learned how to use my intuition rather than mathematical formalism, then to Prof. H. Kroto for endless discussions about science and its purpose, and Profs. A. McCaffery and late W. McCrea all from the Sussex University. Thanks also goes to Profs. A. Dalgarno and W. Klemperer from Harvard University and Prof. D. Kleppner from MIT for a long time collaboration and useful comments that greatly shaped the book. A special thanks goes to Prof. J. P. Toennies from Goettingen for the specially designed experiment for this book (see beginning of Chapter 11). However, above all I must be grateful and thankful to my late father Prof. T. Bosanac who planted in me the seeds of virtues of a scientist: to be inquisitive and open to new ideas without prejudice not only in science but as a way of life, and to be sufficiently critical of my work not to become self–centered. Great role in widening my scientific horizons played the Brijuni Conferences that over the years I had pleasure to organize with my friends from chemistry and physics. Their interdisciplinarity brought about scientists from various fields of research, thus contributing towards better understanding of each other, and being inspirational to go into the uncharted pathways of science.

The book is dedicated to my family and the last sentence goes to them. There is no word to describe my gratitude to my wife Ana, and my daughters Jana and Iva, for all the years of peace and quiet that we had in the family, and not to sound to be egoistic that was the catalysts in my scientific carrier. I only hope that one day they could say that was also the catalysts for their carrier as well.

Slobodan Danko Bosanac
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