Preface

When we look back over historical times we have a feeling that the changes in human society, life style and culture accelerate more and more the closer we approach the present time. This is a very intuitive perception since we have no objective measure of the rate of change, and it may be biased to some extent by the fact that more information in general and therefore also more information about the rate of change is available for the more recent centuries. Should changes indeed accelerate exponentially or even faster then they extrapolate to infinity. Nothing though goes to infinity in nature, so there must be a term that slows down this rapid development and turns it into a critically damped or oscillatory behaviour. This decelerating term may at present not be visible, but its likely presence makes extrapolations into the future extremely difficult.

One of the things which are expected to rush over our globe and change our lives in near future is *nanotechnology*, often termed a key technology of the 21st century. The rate and the extent of the prospected changes are horrendous. The prospects for future generations are therefore loaded with hypes, hopes and fears, and they are difficult to assess reliably. Probably the best thing that we can do to cope with this uncertain future and reduce fears and risky developments is educating as many people as possible to enable them to establish their own and independent judgement. This is the main aim of the present book.

In its strict sense the term nanotechnology is used for methods which permit the manipulation and controlling of *individual* atoms, molecules, or other entities of matter on a nanometer scale. The technology of making and controlling things on a small scale has been in the focus of much of the work during the past decade. Several books have come out on technological aspects, while understanding things has been somewhat in the second row, at least in the chemical discipline. The latter is the more specific focus of the present text.

In a broader sense the term *nanotechnology* includes the application of *nanomaterials*. Nanomaterials are not the products of nanotechnology in its strict sense; rather they represent large amounts of materials in a size range of 1-100 nm which because of their small size adopt a wide variety of properties different from those of the bulk. They are in the focus of materials science which has undergone a veritable revolution over the past decades. Fine powders, compacted or sintered, block-copolymers, organic-inorganic nanocomposite materials, carbon nanotubes and inorganic porous materials derived from sol-gel processes, self-assembled dots and layers, thin films and fibres have found a multitude of applications. Most of these materials have a surface or interfacial area which can be as high as 1000 m^2 per gram and more. Surface effects are no longer negligible; rather, they often dominate many of the properties of practical relevance. They have to be understood in order to permit the manufacturing of materials with tailored properties and sufficient stability. Modern manufacturing technologies aim at mass production, and the interest is in the *collective* rather than the individual property.

Physical chemistry is the science at the intersection between physics, chemistry, and engineering. And yet physical chemistry textbooks around the world have nearly not taken notice of the special size-dependent phenomena of nanosize materials. We continue to teach chemistry students in thermodynamics all possible aspects of *volume work* of ideal gases – things of relevance in combustion and flight engineering. For materials scientists and people involved in nanotechnology it would be much more important to get at least a basic understanding of *surface work* and of other phenomena near interfaces. The present text is intended as a contribution to fill this gap. It wants to introduce this matter on a phenomenological basis, it reports quantitative relations (scaling laws) where available, and it leads the way to original literature where further details may be found.

Many of the basic concepts are not new. Capillary effects and the Gibbs-Thomson equation, for example, have been known for over a century. However, technological progress in recent decades has led to far better control of nanoscale materials. This in turn has presented a challenge on theory and has led to refinements of the original concepts. Moreover, the availability of well defined nanomaterials with new and tailored properties has led to stimulating promises and exciting hopes. Revolutionary electronic elements and devices such as quantum computers are some of the present challenges which are in the focus of many scientists. Already, specially designed nanoparticles are being used as carriers for drugs which permit their distribution in the human body and a controlled release at the target site. On the other side of the medal we have new potential risks which at this point have been largely unexplored. All these prospects have imposed a new weight on the concept of size-dependent phenomena in fundamental and applied research and even in every day life. In order to warrant further progress and success it is essential that these concepts become part of the active, every-day thinking of young people, and it is hoped that this book will contribute to it.

Nanotechnology is a rapidly developing field. A large number of scientists is working hard to push the frontiers further and turn dreams into reality. New publications with exciting new results appear day-for-day. Any book about nanotechnology has to catch the subject on the fly. Since the focus of the present work is on the fundamental principles rather than on what we can do today it is nevertheless hoped that a large fraction of the material covered here will remain valid for some time.

Scientific progress at the frontier of a new field is based entirely on the creativity of the involved scientists. Seminal scientific work therefore needs the freedom to explore what scientists come up with in their dreams. Programmed research may be suitable to achieve a goal in a collaborative effort, but no matter who has defined the program it will never have the flexibility to adapt to such dreams and therefore it will never be creative to the same extent as free research. However, free research does not mean that it is free of responsibility for what it inherits to society and to nature. There is a *personal responsibility of every scientist* to comply with accepted ethical guidelines. It is extremely damaging to the image of science when this is not respected. When scientists or companies value personal benefits higher than benefit to society and nature, then politics will have to set limits. It is quite certain though that specific and appropriate laws will always lag far behind any scientific developments. Lawmakers will try to cope with this situation by increasing the rigidity of the limits, which of course will have the effect that also harmless developments are cut. It is the aim of the last chapter to extrapolate some of the developments into the future and to address some of the ethical bounds involved.

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