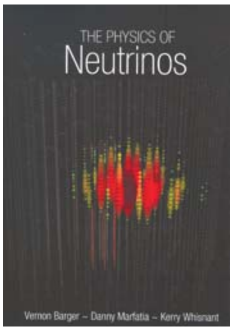

The Physics of Neutrinos. Vernon Barger, Danny Marfatia and Kerry Whisnant. Princeton University Press, Princeton, USA and Oxford, UK. 2012. 240 pp. Price: US$ 99.50.

The book under review is a welcome addition to any scientific library by active scientists working in the field of neutrino physics. Vernon Barger from the University of Wisconsin, Madison, USA is one of the great doyens of elementary particle physics and here he is joined by younger colleagues Danny Marfatia of the University of Kansas, USA and Kerry Whisnant from Iowa State University, USA. The authors start from the basics of the field and provide up-to-date accounts of the complex subject with experimental information constantly as their reference point. Organized in 13 well-written chapters with 176 pages of text, and over 40 pages (!) of references to several thousand original papers with the rest devoted to the index, this will be a great reference book both for beginners as well as practitioners.

It may be pointed out that neutrino physics is a field where theory has often been ahead of experiment as the latter is very difficult to execute and scientists have spent their entire careers patiently sifting through huge amounts of data, often having to content themselves with bettering a bound on a certain property in place of a discovery. Thus, the book can also be viewed as a paean to the efforts of generations of experimentalists who have today given us a comprehensive view of what the properties of neutrinos are.

It may be recalled that Wolfgang Pauli had posited the existence of certain particles to rescue energy and angular momentum conservation in nuclear beta decay even before the discovery of the neutron. Enrico Fermi interpreted the hypothesis to mean the existence of particles he christened neutrinos. Their experimental observation, or more precisely that of anti-neutrinos, was due to Fredrick Reines and Clyde Cowan using nuclear reactors as a source. The subsequent discovery of parity violation in the weak interactions due to T. D. Lee and C. N. Yang led to the hypothesis of the structure of weak currents due to George Sudarshan and Robert Marshak, and Richard Feynman and Murray Gell-Mann, which required neutrinos always to be left-handed and anti-neutrinos to be right-handed, tested soon afterwards by Maurice Goldhaber and co-workers.

Today a lot is known about neutrinos; they are elementary particles and come in three types. They are electrically neutral counterparts of the electron, and one each for the heavier cousins of the electron known as the muon and the tau-lepton. The fact that they are electrically neutral leads to interesting theoretical and experimental richness. In particular, it is now known that these three types of neutrinos now 'mix' amongst each other, and this is described by a mixing-matrix many of whose elements have been determined by generations of experiments. Furthermore, the fact that they mix leads to the oscillation of a neutrino of one type into the other. This oscillation leads to, among other things, a deficit in the observed number of solar neutrinos on Earth, anomalies in the ratios of the number of neutrinos of different types among those produced in decays of particles produced when cosmic rays interact with nitrogen and oxygen nuclei in the Earth's atmosphere. Such oscillations can occur only if the neutrinos are massive. It is hard to believe, but it is a fact, that even in the year 2012, what we know is only the differences of the squares of the masses of the neutrinos, i.e. we do not individually know what the three masses are. We also know the mixing between the electron and muon type is large, and that of the muon and tau-lepton type is practically maximal. After this book went into press, many experiments have reported values for the mixing between the electron and tau-type lepton to be small but not negligible.

Note also that the solar neutrino deficit problem mentioned above requires the large mixing angle to go hand-in-hand with the interaction of the solar neutrinos produced in the core of the Sun with the dense matter present on its journey outwards (Michayev–Smirnov–Wolfenstein mechanism). As mentioned earlier, the fact that the neutrino is massless also means that it could be a window to the violation of another symmetry known as CP (charge-conjugation and parity), which could include up to three CP-violating parameters. There is no experimental information on any of these.

The book under review does a phenomenal job in reviewing the entire field. It points out forcefully that the subject of neutrino physics has matured and flourished due to the efforts of experimentalists and a variety of experiments based on sources known as reactor neutrinos, accelerator neutrinos and astrophysical neutrinos, the latter coming from solar or atmospheric neutrinos. In addition, another remarkable source is those originating in supernova collapse which was first observed in 1987, thereby giving credence to several theories of supernova formation and allowing tests of those, in so far as one could compare the measured rates with those predicted by the theory. In the recent years, specialized experiments have also measured the so-called cosmogenic neutrinos arising from the pion decay produced in the reaction of highly energetic protons with the cosmic microwave background radiation.

The authors skillfully present the material in the form of basics and theoretical description of neutrino mixing and oscillations, and discuss among other things the important subject of matter effects. The two defining issues of solar neutrinos and atmospheric neutrinos are described in separate chapters. The unified treatment of the data takes place in the framework of global three-neutrino fits with a short chapter on experiments and bounds on absolute neutrino masses. Some futuristic trends are noted in the chapter on long-baseline neutrino oscillations. As mentioned earlier, since theory has been ahead of experiment, a detailed description of masses of neutrinos in extensions of the standard model is presented. Supernova neutrinos are described in a separate chapter as well as high-energy astrophysical neutrinos. While it is common theoretical prejudice to simply assume three neutrino types, the question what if there were more is also addressed in a separate chapter as well as interesting questions at the frontier of elementary particle physics. The authors conclude with summary and outlook.

The reader is taken on a tour of experimental methods and data, and through a garden of exotic models for neutrino masses. The reader would appreciate, for instance, that the solar neutrinos are associated with the MeV energy range, and the atmospheric neutrinos are with the GeV energy range. The parameters explaining the first problem are confirmed by so-called reactor neutrino experiments, whereas those explaining the latter by the so-called accelerator experiments.

Of special note is the description of the high-energy astrophysical neutrinos which are explored through such novel experiments at the IceCube experiment in the South Pole that uses clear, naturally occurring ice in the icesheets of the Antarctic.

The present reviewer is also particularly impressed by the chapter on model building. Of special note is the importance given to the see-saw mechanism proposed independently by (a) P. Minkowski, (b) T. Yanagida, (c) the group of M. Gell-Mann, P. Ramond and R. Slansky and (d) R. N. Mohapatra and G. Senjanovic, which appeals to grand unified theories to produce such small masses for neutrinos. This is another example of theory being far ahead of experiment.

Although there have been phenomenal successes in the field of neutrino physics, many questions remain to be answered. In particular, future experiments will shed light on the actual mass hierarchies, since the present information is only on the mass square differences. More needs to be learnt on the issue of the mixing matrices. As mentioned earlier, the fact that neutrinos are electrically neutral implies that they could be either 'Majorana' (named after the romantic and tragic figure Etorre Majorana) or 'Dirac' (named after the eminent physicist Paul Dirac). In the event that they are Majorana, there would be no distinction between neutrinos and anti-neutrinos. Future experiments, including those that are looking for so-called neutrinoless double-beta decay will shed light on this question. Perhaps future accelerator experiments will shed light on the nature of the neutrinos. Doubtless the planned neutrino telescopes will shore up our knowledge of astrophysical and cosmogenic neutrinos. Many of these issues are touched upon in the chapter entitled 'Summary and outlook'. In short, this exciting book takes the reader through a grand tour of the physics of neutrinos and is a delightful read.

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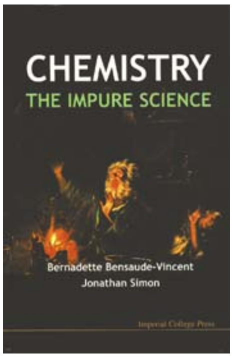
B. ANANTHANARAYAN

Centre for High Energy Physics,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: anant@cts.iisc.ernet.in



Chemistry – The Impure Science. Bernadette Bensaude-Vincent and Jonathan Simon. Imperial College Press, 57, Shelton Street, Covent Garden, London WC2H 9HE. 2010. xii + 268 pp. Price: US$ 97.00.

The twilight years of the eighteenth century signalled a paradigm shift in chemistry that kindled the dawn of modern chemical science[1]. In 1785, Lavoisier showed the public that water thought to be an element from the days of Aristotle is not so. Thomas Jefferson, amongst many other things, was also a chemistry fan with a library of his own[2] and in 1786 he wrote, 'There are some things in this science (chemistry) worth reading'. Nearly 200 years later Nobel Laureate Cyril Hinshelwood would rejoice, 'Chemistry: that most excellent child of intellect and art'. Today chemistry is able to tell us a lot about the world at molecular level as well as at higher levels of aggregation and the future is full of promises[3]. On the other hand, chemical technology has transformed our lives[4].

But there has also been discontent in the academia and the public on grounds of philosophy and health. Like, chemistry is empirical and less fundamental than physics; it promotes consumerism via industries that mass-produce and pollute the environment; it creates artificial objects and is tainted with its alchemical history and so on. The authors of this book are experts of history and philosophy of science, and they sum up the situation by qualifying 'chemistry as the impure science'. They search for the roots of the problem in the history of chemistry, chemical industry and prevalent philosophical and cultural outlooks. They uphold the philosophical legitimacy of chemistry and suggest some ways to improve the image of chemistry. A summary of the book follows.

In chapter 1, the goals and structure of the book are enumerated. In public perception nothing puts chemistry on the spot more than its association with pollution (chapter 2). As an illustration, the ups and downs of the pesticide and polymer (plastics) industries which symbolized the 'brave new world' in the 1960s and 1970s are presented. With pollution control and other improvement steps in place, today's public appreciates the benefits of chemistry but they remain suspicious of it. The memory of war gases and recent accidents like those in Sevoso, Bhopal and Toulouse is not easily forgotten. In chapter 14 which concerns ethical issues it is suggested that apart from greater respect for the environment and stricter risk assessment at the stage of designing products, the scientific and technological choices should be a collective decision involving both chemists and the public. The authors envisage chemistry as a technoscience which can integrate culture and society into its practice.

An image problem originating from Western social roots is much older than that due to pollution. This is the anti-Aristotelian transgression of the frontier between the natural and the artificial attempted by medieval alchemists (chapter 3). But alchemy was not all in vain. Lead may not have become gold, but alchemists acquired real expertise in handling materials and performing reactions. They catalysed the advent of European chemical industry as early as the seventeenth century, which flourished into the next century with patronage of governments seeking economic progress. The natural–artificial crossover theme did not die either. In 1791, Leblanc made artificial (synthetic) soda and above all Whöler made artificial urea in 1828. Chemistry was thus challenging a fundamental social and cultural dogma and has therefore been 'perceived as a threat to Western civilization'. However, the wall between the living and the inanimate worlds continued to loose ground through the nineteenth and twentieth centuries, particularly during the second half of the latter century and now in the nanoworld (chapter 13) it is in virtual ruins.

The laboratory, an isolated space to labour and to know, was also invented by the alchemists. It remained an exclusive place for chemical actions till other experimental sciences emerged and adopted it. The evolution of the chemical laboratory over the past 300 years is sketched in chapter 4. In 1785, Lavoisier used his laboratory for the first time to make