1 Electromagnetic waves and photons

What we call *classical physics* is a body of ideas that developed slowly during the eighteenth and nineteenth centuries. It deals with diverse phenomena, including the motion of material bodies according to Newton's Laws, and the behaviour of electromagnetic fields and waves, such as light. These are linked by some central concepts. Physical systems possess energy, the amount of which is conserved as it passes between different forms. In classical physics there is no restriction on the value of the energy of systems. Another central assumption is that of strict *determinism*: classical systems follow precise mathematical laws, so that if we have enough information about their present state, we can predict as accurately as we like what will happen to them in the future.

By the year 1900, it was possible to believe that physics was almost fully understood. Certainly, there were a few small gaps. The nature of atoms and molecules was still mysterious, and so were the ways in which radiation interacts with matter. But to many physicists these appeared to be minor details, easy to fill in when more information was available, and not likely to entail major new ideas. Within a few years, however, this optimistic view was shattered. The 'small gaps' came to seem fundamental, and a radically new theory was required to fill them. One discovery was that the energy in a system may be restricted to certain discrete values, rather than the unrestricted range allowed in classical theory. The idea of a *quantum*—a certain definite amount of energy—was to provide the name for the new theory. As the understanding of energy quanta developed, other classical concepts also had to be abandoned or modified. The clear distinction between material bodies with definite positions, and waves spread out in space, was one such casualty. The most fundamental change of all was that the strict determinism of classical physics no longer applies in the quantum theory. Systems change in ways which cannot be predicted precisely; only the probability of different events can be predicted. A familiar example is the radioactive decay of an atom. Although we may know the probability that a given atom will decay in a given time, the quantum theory denies the possibility of ever being able to predict exactly *when* it will decay.

The word *quantum* is originally Latin, meaning *how much?* Its plural is *quanta*.

Classical physics remains an excellent approximation to much of the behaviour of bodies on a macroscopic scale. It is in the microscopic realm that the quantum theory is essential. The behaviour of electrons in atoms and molecules, and the nature of the chemical bond, are among the problems that classical physics is unable to describe. It was only following the development of the quantum theory that chemists could really use physical ideas to provide a satisfactory understanding of their own problems.