THE NATURE OF X-RAYS, THEIR PRODUCTION AND INTERACTION

X-rays form part of the electromagnetic spectrum together with radiation such as radio waves and light. Radio waves, which lie at one end of this spectrum, have a long wavelength but are of low energy; X-rays on the other hand have a short wavelength but are of high energy.

X-rays were discovered in 1895 by Conrad Roentgen and were so-called because at that time the nature of the radiation was unknown. Later it was realized that X-rays were the same as gamma radiation. However, the beam generated by an X-ray tube (Figure 4.1) consists of X-ray photons with a range of different energies, whereas gamma rays that are produced by a radioactive source are of a single energy characteristic of that particular isotope. X-rays are produced in the X-ray tube by bombarding a tungsten target with a stream of electrons, accelerated by a high voltage (typically of 60–70 kV for a dental unit). The process is very inefficient, with only approximately 1% of the energy from the electron stream going into X-rays, 99% being lost as heat.

The larger the voltage, the greater will be the maximum energy of the X-ray photons within the beam, increasing its penetrative power (Figure 4.2). There will still be a range of energies, and this is of fundamental importance to the creation of a radiographic image, as it enhances the differential absorption of the beam by the different tissues of the body. Very-low-energy photons, however,

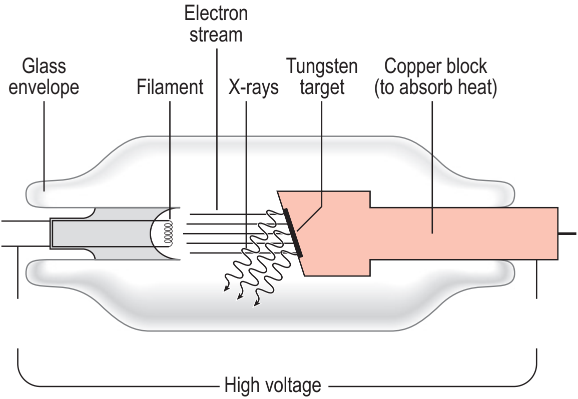

Figure 4.1 X-ray tube.

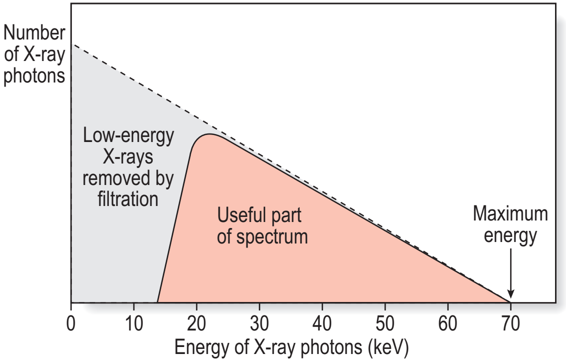

Figure 4.2 X-ray spectrum produced at 70 kV.

would not contribute to the radiographic image, being immediately absorbed by the skin. These are removed using an aluminium filter. The current flowing though the X-ray tube (typically 8–10 mA) will determine the quantity of X-rays produced. The higher the current the less time will be required for the exposure. However, many dental radiography sets have a fixed current, leaving the operator only to adjust the time.

When X-ray photons enter the body, two main interactions occur: *photoelectric absorption* and *Compton scatter*.

PHOTOELECTRIC ABSORPTION

The photoelectric effect predominates with lower-energy photons, the likelihood of this interaction occurring varying with the atomic number (Z) of the tissue. The probability is proportional to Z^3; consequently there is a big difference between the absorption by bone ($Z^3 = 1728$) and soft tissues ($Z^3 = 343$), which is why there is good contrast between these structures on a radiograph, particularly where a relatively low voltage (usually referred to as kV) is used.

COMPTON SCATTER

Compton scatter is the predominant interaction produced by high-energy photons and is not dependent on the atomic number. This accounts for the fact that as the voltage is raised there is less contrast between different tissues.