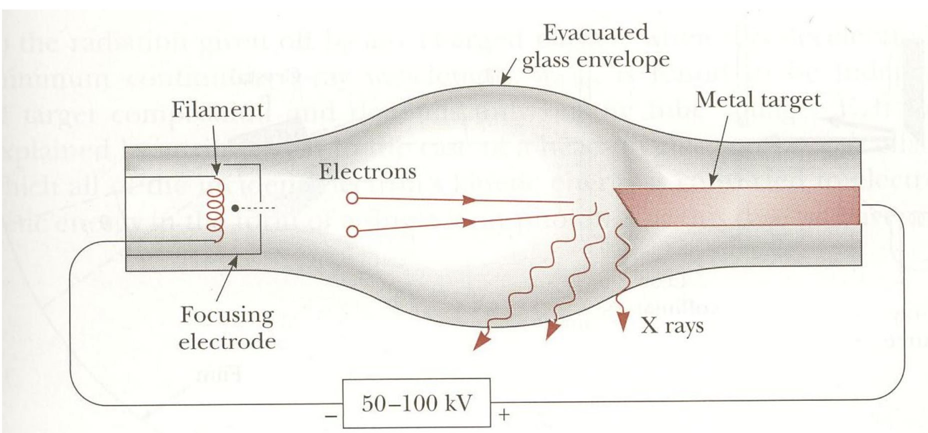
X-RAYS

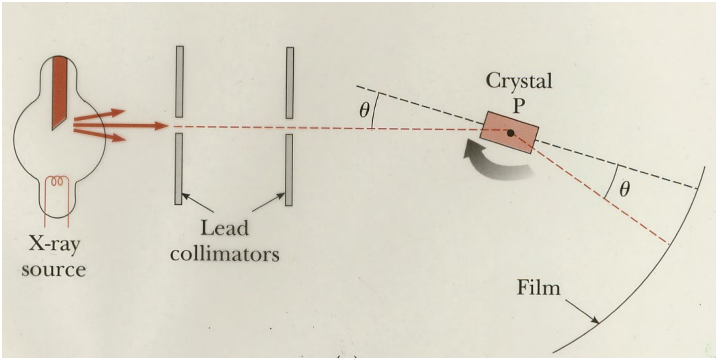
Einstein's explanation of the photoelectric effect suggested that light travels in discrete bundles of energy called photons which carry energy and momentum. Such a model suggested that photons, and thus light, behaves like particles. This was confirmed experimentally in 1923 in a famous experiment called the Compton Effect by analyzing the scattering of x-rays from electrons

In 1895 the German physicist Wilhelm Roentgen discovered X-rays. He was unable to deflect the rays in a magnetic field and unable to observe refraction or diffraction and thus gave them the mysterious name of X-rays. Experiments later confirmed that X-rays were a form of radiation (photons) with extreme short wavelength $\approx 10^{-10}$m. That is, X-rays are high energy photons.

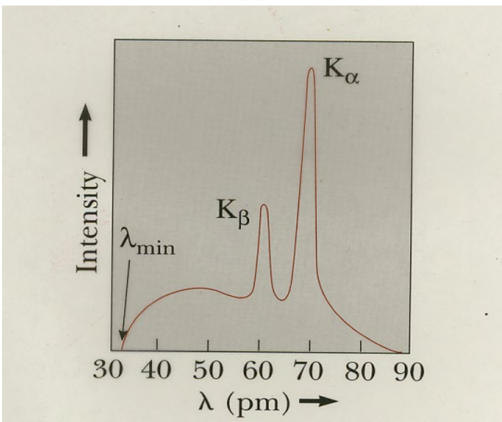
X-rays are produced by the deceleration of electrons as they move toward a target metal. As electrons move toward a metal target they will decelerate due to the electric forces of the electrons surrounding the nucleus of the atoms in the metal target. As a result of the deceleration they will emit radiation called X-Rays.



The X-rays can be analyzed more carefully by producing a concentrated X-ray beam with the use of lead collimators. The X-rays can then be directed toward a crystal and then toward a detector to be analyzed.



(a)



(b)

The resulting X-Ray spectrum produced by the metal target has very important characteristics that need to explained.

1. The spectrum is a broad continuous spectrum (Bremsstralung – braking radiation).
2. The continuous spectrum has a sharp cutoff wavelength λ_{min} which is independent of the target metal and depends only on the accelerating voltage of the electrons.
3. Superimposed on the continuous spectrum there are a series of sharp X-ray lines. These sharp lines are characteristic of the target metal and varies from element to element.

A. The broad continuous spectrum is due to the indirect scattering of electrons from atoms in the target metal.
B. The sharp cutoff wavelength λ_{min} was explained by Einstein as being the inverse of the photoelectric effect. In this inverse process an electron gives all of its energy to a single photon:

$$K_{\max} = hf - \phi$$
$$eV \approx hf \quad \text{(since } \phi \text{ is neglible)}$$
$$eV \approx h\frac{c}{\lambda}$$
$$\lambda = \frac{hc}{eV}$$
$$\lambda = \frac{1240\ ev\square nm}{eV}$$

C. The series of sharp X-Ray lines occurs when an accelerating electron has sufficient energy to penetrate the atom and remove one of the inner core electrons. When one of the inner core electrons is removed it leaves a vacancy. A higher energy electron then falls to this lower energy level and emits a high energy X-ray (photon) which is shown as a sharp line on the X-ray spectrum.