



Department of Radiological Techniques  
Second Stage - Radiation Physics Lab.

# Characteristic X-Ray of Tungsten

## Lecture 4

By

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## ➤ The aim of this experiment

Spectra of X-rays from a tungsten anode analyzed

## ➤ The devices used in this experiment

1. An X-ray tube with a tungsten anode generates X-radiation that is selected with the aid of a monocrystal as a function of the Bragg angle.
2. A Geiger-Müller counter tube measures the intensity of the radiation.
3. The glancing angles of the characteristic X-ray lines are then used to determine the energy.



## ➤ Theory

Most x-ray tubes use tungsten, which has an atomic number of 74, as the anode material. In addition to a high atomic number, tungsten has several other characteristics that make it suited for this purpose. Tungsten is almost unique in its ability to maintain its strength at high temperatures, and it has a high melting point and a relatively low rate of evaporation.

When electrons hit the metallic anode of the x-ray tube with high kinetic energy, x-rays with a continuous energy distribution (bremsstrahlung) are generated. The bremsstrahlung is superimposed by additional discrete lines. If an atom of the anode material is ionized, for example, in a deeper shell by an electron impact, an electron from a higher shell can take the now free place while emitting inter alia an x-ray quantum. The energy of this x-ray quantum corresponds to the energy difference between the two levels that are involved in this process. Since the energy difference is atom-specific, the radiation that is generated by this process is also called the characteristic x-radiation.

When an x-ray with the wavelength  $\lambda$  hits the group of lattice planes of a monocrystal at the glancing angle  $\theta$ , the rays that are reflected by the lattice planes only interfere in a constructive manner, if their path difference  $\Delta$  corresponds to an integer of the wavelength. This condition is represented by the so-called Bragg's law:

$$2d \cdot \sin\theta = n \cdot \lambda \quad \dots(1)$$

( $d$  = interplanar spacing;  $n = 1, 2, 3, \dots$ )

If the interplanar spacing  $d$  is known, the wavelength  $\lambda$  can be determined based on the glancing angle  $\theta$ . The energy  $E$  of the radiation then results from:

$$E = h \cdot f = \frac{h \cdot c}{\lambda} \quad \dots(2)$$

(1) and (2) finally leads to:

$$E = \frac{n \cdot h \cdot c}{2d \cdot \sin\theta}$$

## ➤ The method of work

1. Connect the goniometer and the counter tube to the appropriate sockets in the experimenting area (see red marking in Fig 2).
2. Fix a diaphragm tube in the X-ray outlet tube (2 mm tube diameter).
3. Set the goniometer block with mounted analyzing crystal to the right position and the counter tube to the right stop.
4. Do not forget to install the diaphragm of the G.M. tube (See Fig. 3).



Fig. 2: Connections in the experimentation area.

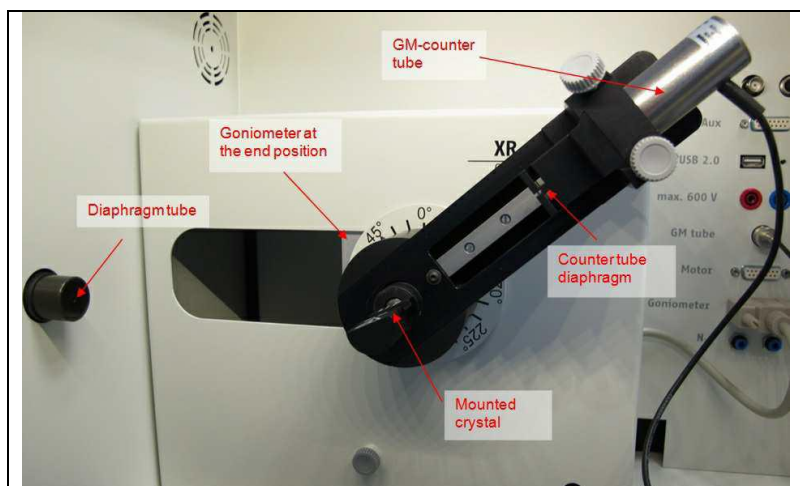


Fig. 3: Set-up of the goniometer.

## ➤ Experiment Result

The X-ray spectrum of tungsten was analyzed with a LiF monocrystal. Well-defined lines are superimposed on the continuous bremspectrum. The glancing angles of these lines remain unaltered when the anode voltage is varied. This indicates that these lines are characteristic X-ray lines.