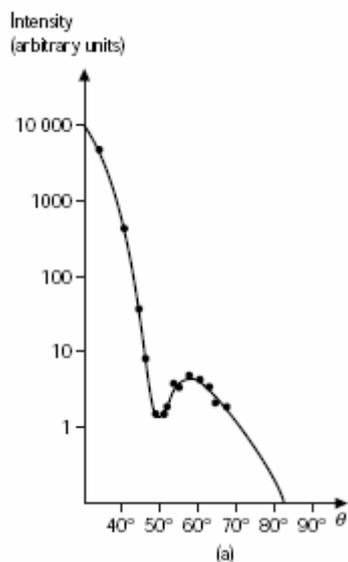# TAP 506-3: Interpreting electron diffraction patterns

For this question to make sense, students need to be aware that an obstacle (e.g. a nucleus) is equivalent to a 'hole' of the same size. So far they have only met diffraction by 'gaps'.

Use the electron diffraction patterns shown in Figures (a) and (b) to determine the diameters of carbon and oxygen nuclei.

(a)

The diffraction patterns represented by the two graphs in Figures (a) and (b) were obtained using electrons accelerated to 420 MV.

(b)
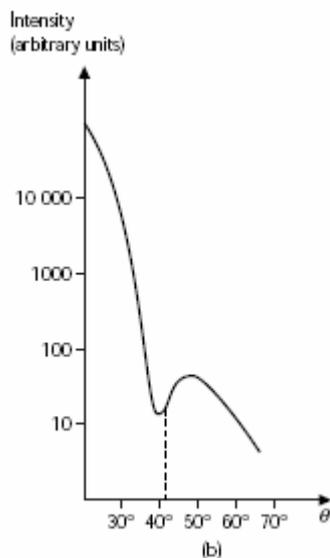
By following the steps below, you will get a flavour of how such diffraction data are interpreted.

You will also see some of the equations that must be used when electrons are moving at relativistic speeds (that is, close to the speed of light).

Calculate the kinetic energy E_k of an electron accelerated through 420 MV.

To calculate the momentum of the electron, you cannot use p=mv and E_K = ½ mv², because these equations don't apply to relativistic particles.

Instead, it turns out that the electron's momentum p is related to its kinetic energy by

E_k ~ pc

where c is the speed of light.

Calculate the momentum of the electron.

The de Broglie relationship

p = hλ

applies to relativistic and non-relativistic electrons because Relativity Theory is used in its derivation.

Calculate the electron's de Broglie wavelength.

The angle of the first minimum θ_{min} on the graph is a clearly identifiable point, and this is used to calculate the diameter of the nuclei.

From the graphs in Figure (a) and (b), determine the angle of the first minimum for carbon nuclei, and for oxygen nuclei.

The smaller the nucleus, the more it diffracts the electrons.

From the angles you found, which are smaller, carbon nuclei or oxygen nuclei? Is this what you would expect from their atomic numbers?

The diameter d of the nucleus is related to the electron wavelength and the diffraction angle θ_{min} by

$$d = \frac{1.22\,\lambda}{\theta_{min}}$$

Use this relationship to obtain estimates of the diameters of carbon and oxygen nuclei.

Explain why your answers are only estimates.

External references

Answers and worked solutions

$E_k = 420 \times 10^6 \times 1.60 \times 10^{-19} = 6.72 \times 10^{-11}$ J

$E_k \sim pc$

so $p = 6.72 \times 10^{-11} / 3 \times 10^8 = 2.24 \times 10^{-19}$ N s

$\lambda = h/p = 6.63 \times 10^{-34} / 2.24 \times 10^{-19}. = 2.96 \times 10^{-15}$ m

(a)   carbon nuclei, 50°
(b)   oxygen nuclei. 42°

$d = \dfrac{1.22\lambda}{\theta_{min}}$

where d is the diameter of the nucleus

Remember, the angle should be in radians or use sin θ.

(a)   carbon d = $(1.22 \times 2.96 \times 10^{-15}) / 0.766 = 4.7 \times 10^{-15}$ m
(b)   oxygen d = $(1.22 \times 2.96 \times 10^{-15}) / 0.669 = 5.3 \times 10^{-15}$ m