

Lab #9

Electron Diffraction

1. Objectives

To observe the wave properties of electrons and to use these properties and Bragg scattering to measure the spacing between carbon atoms.

2. Apparatus

Electron diffraction tube, high voltage power supply, 6.3 volt AC power supply, vernier calipers.

3. Theory

The electron diffraction tube consists of an electron “gun” which is essentially a cathode heated to a high temperature, at which point electrons are emitted by a process known as thermionic emission. These electrons are then accelerated through a high voltage so that they arrive at a thin layer of graphite. The atoms of graphite act somewhat like a grating and the scattered electron waves interfere to produce what is called a diffraction pattern. The spacing between carbon atoms are just about of the same order of magnitude as the wavelength of these electrons.

4. Procedure

- a) Connect the tube into the circuit shown below. The 6.3 volt is connected to the heater supply for the electron gun while the high voltage (2500 to 5000 V) is connected to the anode to accelerate the electrons. Switch on the heater supply and let the tube warm up a minute.
- b) Set the high voltage source at some value between 2500 and 500 volts and switch on the high power supply. Two prominent diffraction rings about a central maximum should appear. Measure the diameter of each ring. These are both first order maxima, the two rings corresponding to the two possible values of the spacing between carbon atoms (0.213 nm or 0.123 nm) (see figure 1)
Because electrons will not be all traveling at exactly the same speed, the rings will not be perfectly thin. When measuring the diameters, estimate the uncertainty by also measuring the thickness of each ring.
- c) Repeat the previous step while varying the voltage in steps of 400 to 500 V for a total of 5 readings.

5. Analysis

The deBroglie wavelength of an electron is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}, \text{ when } v \ll c$$

The velocity of the electron is determined from the accelerating voltage V . Assuming that the electrons are produced from the electron “gun” with a negligible initial velocity; it will acquire a velocity v equal to:

$$eV = \frac{mv^2}{2}, \quad \text{or} \quad v = \sqrt{\frac{2eV}{m}}$$

which means that: $\lambda = \frac{h}{\sqrt{2eVm}}$

The beam of electrons will then pass through a very thin piece of graphite. The diffraction rings observed are those that correspond to spacing in the carbon atoms of $d = 1.23 \text{ \AA}$ and 2.13 \AA . ($1 \text{ \AA} = 10^{-10} \text{ m}$)

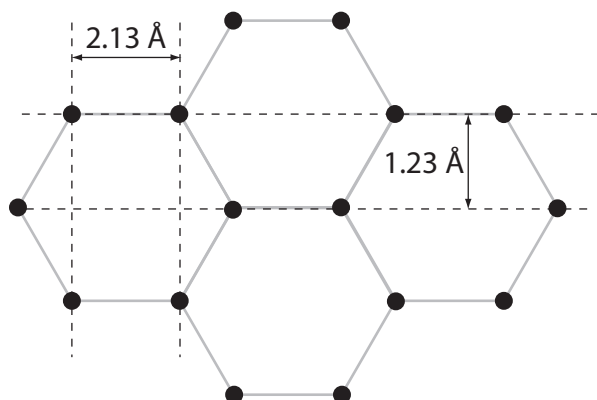


Figure 1: Hexagonal structure of carbon in its graphite form

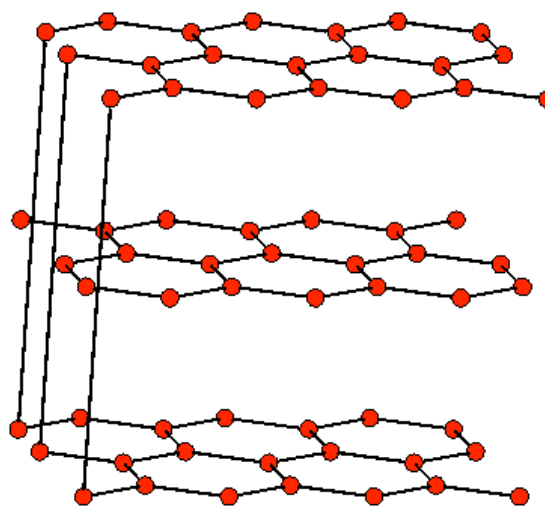


Figure 2: Crystal structure of graphite
(www.everyscience.com/Chemistry/Inorganic/Carbon/images/graphite2.gif).

Visit (www.edinformatics.com/interactive_molecules/carbon_jmol.htm) for an interactive model of carbon in its three crystalline forms: graphite, diamond and fullrene.

The rings formed represent the first order maxima and these are formed when

$$2d \sin \theta = \lambda = \frac{h}{\sqrt{2eVm}}$$

As in ordinary reflection, the incident angle (θ) equals the reflected angle so that the angular separation between incident and reflected electrons equals 2θ (see fig 3 and 4). The angle θ in the previous equation can be determined from noting that:

$$\tan 2\theta = \frac{R}{L}$$

where L is the distance from the graphite to the screen and has been measured to be 13.5 cm.

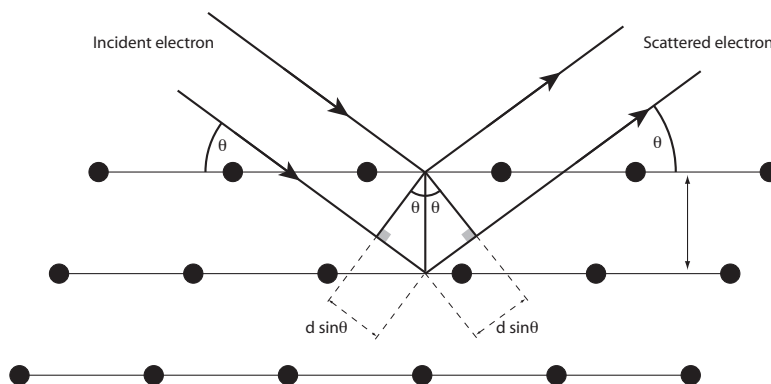


Figure 3: Bragg reflection from two adjacent lattice planes separated by a distance d .

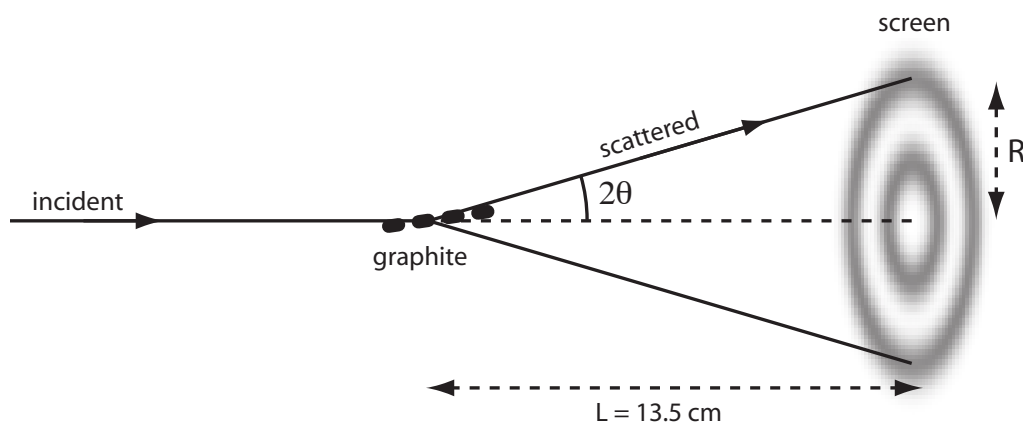


Figure 4: The Bragg angle θ is just half the total angle by which the incident beam is deflected.

6. Analysis

For each ring, plot a graph of $\sin \theta$ vs. $1/\sqrt{V}$ and from the slopes determine the 2 values for d . Compare these with the values given in Figure 1.