ELECTRON DIFFRACTION

Objective: Test the de Broglie relation by measuring the lattice spacing of atoms in graphite using electron diffraction.

Preparation: To be done *before* starting the lab.

1. Read the sections 6.1 thorough 6.3 in the textbook.

2. In this experiment, a beam of electrons is sent through a thin layer of powdered graphite crystals. If the de Broglie hypothesis is correct, the crystals will act like a diffraction grating (see Figure 1). The result-

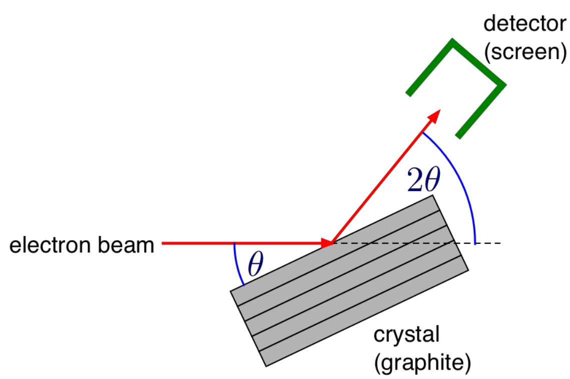

Figure 1: Electron beam geometry for Bragg's law. Note that the angle between the incident electron beam and the electron beam is 2θ.

ing ring-shaped interference pattern has maximum intensity at angles specified by Bragg's law

$$2d\sin\theta = n\lambda, \tag{1}$$

where d is the separation between lattice planes, n is the order of the diffraction, λ is the wavelength of the electrons, and θ is the angle between the plane of atoms off which the beam of electrons reflects and the reflected beam. In this experiment the diffracted electrons are "seen" when they strike a phosphor screen a distance L from the point of scattering as is shown in Figure 2. Show that for small angles,

$$2\theta = \frac{r}{L}, \tag{2}$$

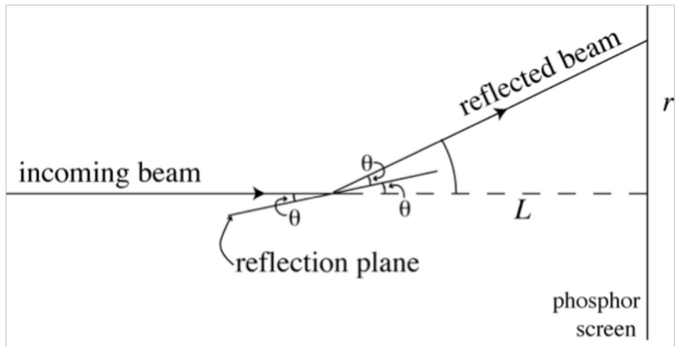

Figure 2: Electron beam geometry for Bragg's law. Note that the angle between the incident electron beam and the diffracted beam is 2θ.

where r is the distance from the center of the phosphor screen to the ring.

3. The electron beam is created by accelerating electrons through a voltage V. Use conservation of energy to find an expression for the wavelength λ of the electrons in terms of the accelerating voltage V and known constants.

4. Use this relation between wavelength λ and V, Equation (1), and Equation (2) to find a relationship relating the diameter D of a diffraction ring to the accelerating voltage. Your result should have the form:

$$D = \frac{k}{\sqrt{V}}, \tag{3}$$

where k is a constant that includes the lattice spacing d and known constants.

5. In this experiment, two diffraction rings will be visible. Each ring corresponds to a particular separation between lattice planes, as indicated in the Figure 3 depicting the crystalline structure of graphite. Your goal is to determine the lattice distances d_1 and d_2 experimentally.

Procedure: Before you turn anything on examine the apparatus and make sure you understand how it works. Ask your lab instructor for a quick check-out before you begin to take data.

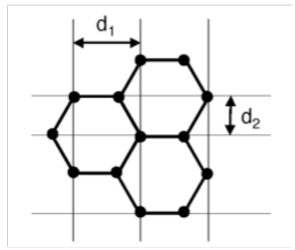

Figure 3: The crystal structure of graphite. Your goal is to determine the lattice distances d_1 and d_2 experimentally.

1. Before turning on the power supply, make sure the accelerating voltage control is turned all the way down.

2. Gradually turn up the voltage. Diffraction rings should begin to appear.

3. Use the calipers to measure the *diameters* of the two rings for a variety of voltages between 3 and 5 kV. Don't assume that the rings are perfect circles—which means that you should take about four measurements of the diameter at different angles. When you are done, turn the equipment off.

Analysis: Create a plots D versus $1/\sqrt{V}$ for each ring (make two separate plots). Plot all the D values you measured. You don't need to average the different D values for a given V. Just plot them up and do a linear fit to the data. Use your fit values for the k to determine the two different lattice spacings d_1 and d_2. Don't forget to include uncertainty estimates. You will have to use the equations for error propagation correctly to get the uncertainness in d_1 and d_2 from the uncertainties the slopes.

Interpretation and Summary: Answer the following questions.

1. Do your results support the de Broglie hypothesis?

2. Do your measured values for the lattice spacings agree with the accepted values of 0.213 nm and 0.123 nm? In this experiment, there are a few different reasons you might not get good agreement. If you find that there is poor agreement there are three places to start looking for the problem. One problem might be an incorrect assumption in the

theoretical derivation of Equation (3), another might be an error in making the measurements, the third might be an underestimate of the uncertainty.

3. How does the electron wavelength compare to the lattice spacing?