Experiment

Investigating Electron Diffraction

Instructions

1. Read the document
2. Complete the experiment, filling the the relevant data
3. Draw an appropriate graph and form an appropriate conclusion and evaluation.

Aim

To determine the spacing between the planes in the atomic lattice of graphite, using the de Broglie Relationship, $\lambda = \frac{h}{p}$.

Theory

According to de Broglie, the relationship between the wave-like and particle-like properties of an electron are related such that:

$$\lambda = \frac{h}{p}$$

λ is the de Broglie wavelength of the electron;
h is Planck's Constant;
p is the momentum of the electron

Electrons can be treated as particles as they accelerate through the potential difference within the electron gun. The electric potential energy of the electron ($W = eV$) is transferred into kinetic energy of the electron. Assuming this transfer is $100\,\%$ efficient, then:

$$eV = \frac{1}{2}mv^2$$

Using the potential difference across the anode and cathode, it is possible to determine the momentum, p, of the electrons:

$$p = \sqrt{2meV}$$

and hence calculate the expected de Broglie wavelength, λ, of the electron.

At this potential difference, the electrons will pass through the thin graphite film and diffract. At this stage, the electrons act as waves and have their own de Broglie wavelength. The wavelength can be calculated using Bragg's Law:

$$n\lambda = 2d sin\theta$$

n is an integer determined by the order given;
λ is the de Broglie wavelength of the electron;
θ is the angle between the central point of the diffraction pattern and the order given. (n=1 is used in this experiment)

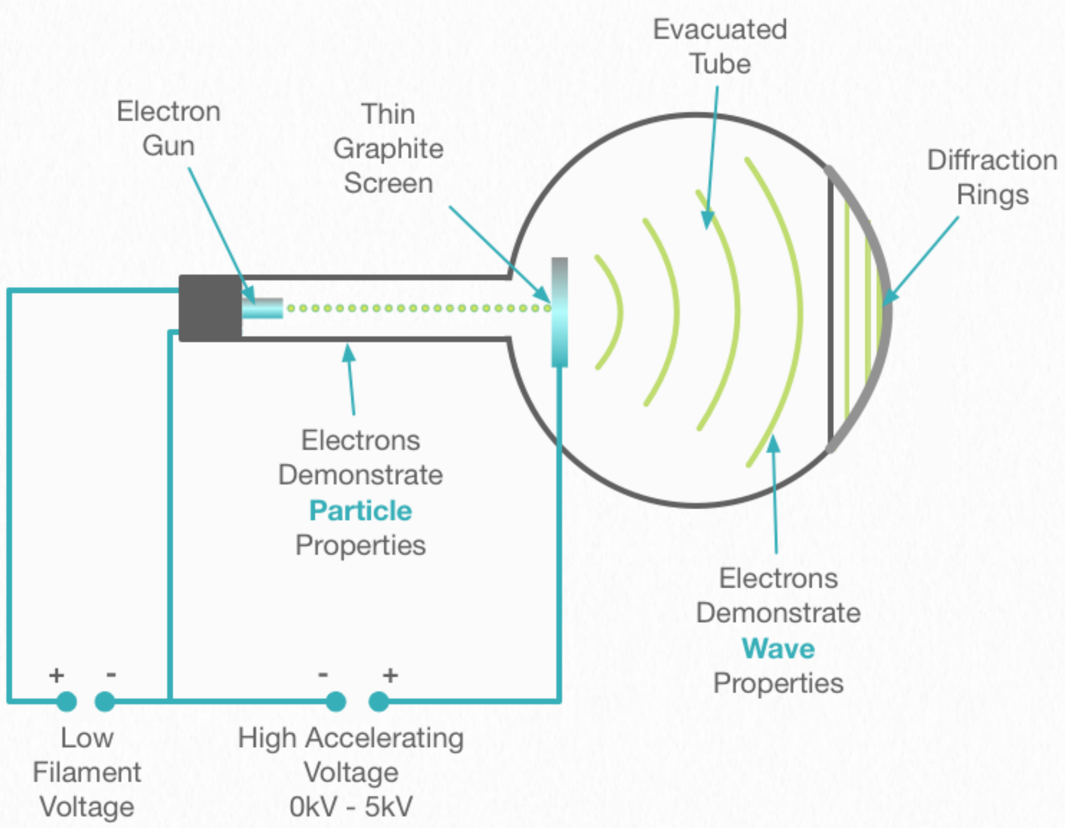
Experiment Continued

Variables

Variable	Description
Independent Variable	**Accelerating voltage, V (V)**, which allows the momentum and hence the de Broglie wavelength of the electrons at different voltages to be calculated.
Dependent Variable	**Distance between the central point of the diffraction pattern and the 1st order maximum.** This allows the angle, θ, to be found using trigonometry. Hence $\sin\theta$ can be calculated.
Control Variable	**Same crystalline structure** **Same evacuated tube** **Same distance from thin graphite film to phosphorus screen.**

Required Resources	
Electron Diffraction Tube	4mm Leads
EHT Unit	Ruler
Low Voltage Supply	Meter Ruler

Diagram



Safety Alert
Leads must have shrouded connectors and insulation capable of withstanding 5kV. Do not adjust connections while the EHT is on.

Experiment Continued

Data Table	
Mass of Electron: $m_e = 9.1x10^{-31}kg$	Planck Constant: $h = 6.63x10^{-34}Js$
Charge on Electron: $e^- = -1.6x10^{-19}J$	Speed of Light: $c = 3x10^8 ms^{-1}$

Method

1. Connect the low voltage supply across the heater. It should be set at about 5-7V.
2. Connect the high voltage supply across the anode and cathode. This is called the accelerating voltage and should be set to about 5kV.
3. Switch on the apparatus. You should see a diffraction pattern emerging on the phosphorus screen.
4. Read the exact value of the accelerating voltage. Note this in the data table (ignore errors).
5. Use $p = \sqrt{2meV}$ to calculate the associated momentum of the electrons. Use the de Broglie equation to determine the wavelength of the electrons. Note this in the table.
6. Measure the distance between the central point of the diffraction pattern and the 1st order maximum, D, in meters. Note this in the table. However, the 1st order maximum is often difficult to measure. If difficulties occur measuring the 1st order use the second order instead (remember that $n = 2$ in this case).
7. Measure the distance between the thin graphite film and the phosphorus screen. Note this here __________m.
8. Calculate the angle θ using trigonometry. Note this angle in the table below.
9. Calculate $sin\theta$ and note this in the table.
10. Repeat steps 1-9 using a different accelerating voltage. You should use the range 2.5kV to 5kV, in steps of 0.5kV.
11. Plot a graph of λ (y-axis) and $sin\theta$ (x-axis)
12. Use the gradient of the graph to find the spacing between the carbon atoms in the lattice of graphite, $d(m)$.

Data

Accelerating Voltage, *V (V)*	Momentum of electrons, *p (kgms⁻¹)*	de Broglie Wavelength of electrons, *λ (m)*	Distance between central point and 1st order maximum *D, (m)*	*θ (degrees)*	*sinθ*

Graph

Plot a graph of λ (y-axis) and $sin\theta$ (x-axis). Use $gradient = \frac{2d}{n}$ to find the spacing between the atomic planes in the lattice of the graphite, $d(m)$.

Experiment Continued

Conclusion

1. Describe the pattern or trend shown on the graph
2. Are there any anomalies?
3. Use the gradient to find the value of d in meters.
4. Comment upon the reliability of the results, by analyzing the spread of points around the line of best fit.
5. The actual value for the spacing between the carbon atoms in the lattice of graphite is $1.42x10^{-10}m$. Calculate the percentage difference between the experimental value obtained and the actual value for the spacing between the carbon atoms in the lattice of graphite.

Evaluation

1. Comment upon the design and method of the experiment.
2. Comment upon the quality of the data.
3. List the weaknesses and discuss how significant the weaknesses are.
4. Suggest an improvement for each of the weaknesses highlighted above.
5. Modification of experimental technique and data range should be addressed, if necessary.