Bragg Diffraction Experiment

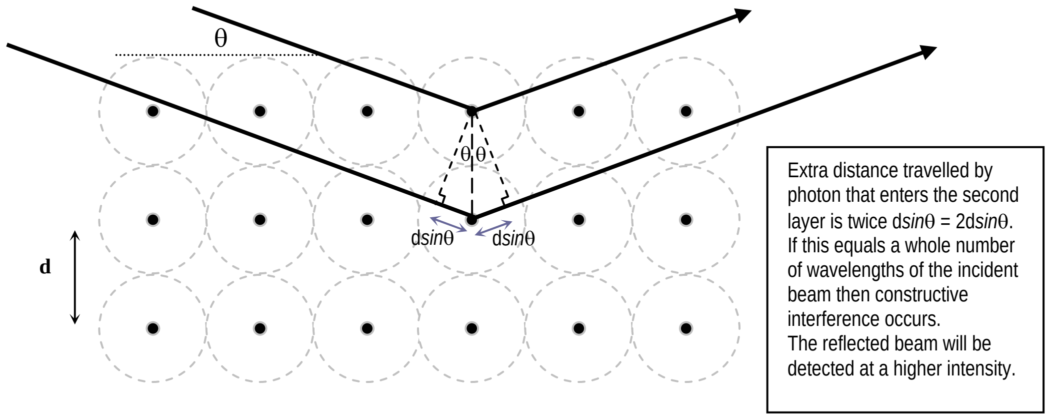
BACKGROUND THEORY

Bragg’s Law derived in 1913 by the English physicists Sir W.H. Bragg and his son Sir W.L. Bragg to explain why crystals appear to reflect X-ray beams at certain angles of incidence.

Bragg's Law: $n\lambda = 2d\sin\theta$

Where ***d*** is the distance between atomic layers in a crystal,
λ is the wavelength in metres of the incident beam,
θ is the angle of incidence; and
n is an integer representing the number of wavelengths required for constructive interference to occur. At the smallest angle of incidence (θ) for a maxima ***n*** = 1, at the next smallest angle ***n*** = 2, etc.

Bragg’s Law is an example of X-ray wave interference or X-ray diffraction (XRD), and is used to determine the atomic structure of crystals.
The Braggs were awarded the Nobel Prize in physics in 1915 for their work in determining crystal structures (NaCl, ZnS and diamond).



Although Bragg's law was used to explain the interference pattern of X-rays scattered by crystals, diffraction has been developed to study the structure of all kinds of matter with a beam, as long as the wavelength used is comparable to the spacing of the molecules (or atoms) within the object under investigation.

In this experiment microwaves will be used with a frequency roughly 1/50,000th lower than the X-rays the Bragg’s used. This will allow the measurement of crystal spacings 50,000 times greater than those found in compounds such as diamond or sodium chloride (NaCl).

APPARATUS

Microwave transmitter and receiver
'Foam Crystal'
Large Protractor
2 × 1 metre ruler
Aluminium barrier

METHOD PART A

1. Align one straight edge of the 'foam crystal' along the base of the large protractor as shown in figure 1.
2. Place the aluminium sheet barrier on the 90^o line of the protractor.
3. Place the microwave transmitter and receiver on the small blocks provided to raise them off the desk surface.
4. Point the microwave transmitter toward the face of the 'foam crystal' at an initial angle of ~30^o. Similarly align the receiver at 30^o to the face of the 'foam crystal' to detect the reflected beam. See figure 1. (Hint: using 1 metre rulers to align the receiver and transmitter can save considerable time in setting up)
5. Set the transmitter to the CW (continuous wave) and switch on.

CAUTION: Never allow the transmitter to be directed towards a person's eyes at any time. Damage to the retinas is possible!

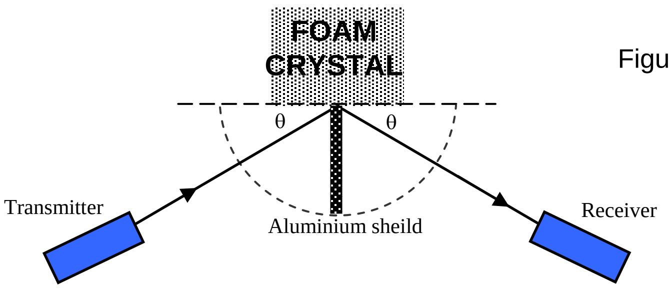


Figure 1

6. Switch the receiver on and use the gain control (1 – 4) to adjust the sensitivity of the meter.
7. Gradually move both the transmitter and receiver closer to the 'foam crystal' face by reducing the angle. Ensure both devices are at the same angle at the same time.
8. Record any angles (θ) when a marked increase is detected by the receiver.
9. Reset the apparatus as in steps 1→3 and repeat but gradually increase the value of θ this time. Each new peak will represent a value for n
10. Use Bragg's Law to determine the spacing of the molecules in the 'foam crystal' in this plane.
11. Repeat steps 1→9 with the 'foam crystal' now placed on its side. See Figure 2.
12. Draw a 3-D model of the molecular structure of the 'foam crystal'

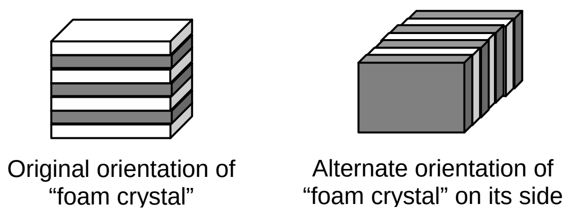


Figure 2.

RESULTS

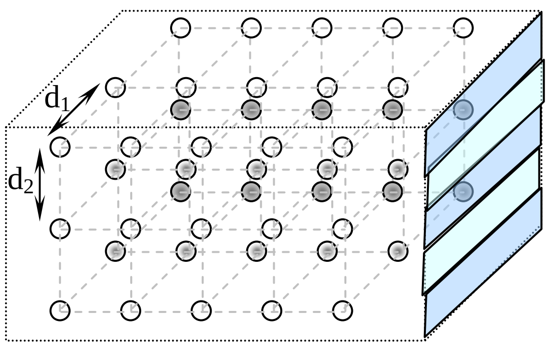
Record the angle (θ) at which maximum readings were recorded for each orientation of the 'foam crystal'. Stop if $\theta = 90^o$. You do not need to fill in every line.

Original Orientation		Alternate (side) Orientation	
n	***θ***	***n***	***θ***
1		1	
2		2	
3		3	
4		4	
5		5	

Calculations using Bragg's Law to determine the spacing (***d***) of the molecules:
$d = n\lambda/2\sin\theta$ (microwave wavelength, λ = 2.8 cm)

Original Orientation	Alternate (side) Orientation

3-D Model of 'Foam Crystal'



PART B Powder Diffraction

1. Place the ‘foam crystal’ in a cardboard or opaque plastic container, so that the orientation of the face cannot be seen. This container hides the direction of the face.
2. Place the container on the protractor randomly. Ensure that the ‘foam crystal’ overlaps the straight edge.
3. Place the transmitter on the 0^o line and put the aluminium barrier against the box edge on the 90^o line again.
4. Move the receiver slowly from 0^o towards 90^o recording any angles of high intensity.
5. This time the angle recorded will equal 2θ.
6. Calculate the molecular spacing.
7. Predict which face of the ‘foam crystal’ the transmitter is directed at. Use your answers from PART A to assist you.
8. Open the container and check your prediction.

CONCLUSION

Which of the methods (Part A or B) was easiest to actually perform? Explain your choice.