

5.61 Lecture #2S: Geiger–Marsden Revisited

A student asked me a question after the September 6 lecture that made me realize that my discussion of the Geiger-Marsden experiment was too glib. There is an excellent discussion of the experiment in Karplus and Porter, *Atoms and Molecules*, Benjamin (1970), pages 18–20. But several key questions remain:

1. Why were α^+ -particles rather than electrons used?
2. How is this experiment different from the Compton scattering experiment in which diffraction rings were observed? How can the back-scattering observed by Geiger and Marsden be distinguished from diffraction of the α^+ -particle by the crystal lattice structure of the metal foil used?

Answers

α^+ -particles are much heavier (almost by a factor of 10^4) than electrons. They are also a product of radioactive decay. They are formed with higher kinetic energy than was possible for electrons in 1911, as Robert van de Graff did not build his high voltage source (at MIT) until the early 1930s. Thus α^+ -particles are easily available in the laboratory with

$$\lambda = \frac{h}{[2m_{\alpha^+} \text{KE}]^{1/2}} < 10^{-2} \text{\AA}$$

and, in 1911

$$\lambda_{\alpha^+} \ll \lambda_{e^-}.$$

The diffraction equation, where $d \approx 1 \text{\AA}$,

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

$$\frac{n\lambda}{2d} = \sin \theta \ll 0.01 \quad \text{for } \alpha^+$$

implies that the diffraction rings associated with the metal crystal lattice would be of ignorably small diameter. This would at worst result in a tiny spreading of the $\theta = 0$ spot on the detector screen in the forward direction.

The wave character of the α^+ -particle is therefore not relevant to the Geiger–Marsden experiment. The α^+ -particle acts as a positively charged (2^+) particle. The angular distribution of the α^+ -particles scattered by heavy metal atoms in the target foil is consistent with nearly all of the atomic mass (known at the time) being located within a positively charged (a charge equal to the atomic number) sphere with radius $\sim 10^{-4}\text{\AA}$. The scattering results from Coulomb repulsion.

MIT OpenCourseWare
<http://ocw.mit.edu>

5.61 Physical Chemistry
Fall 2013

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.