Henry Moseley X-Ray Activity

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 By measuring the Ka and La x-ray lines characteristic of 38 elements in 1913-1914, Henry Moseley was able to make a powerful argument that the atomic number of an element in the periodic table was equal to the number of positive electric charges in the atomic nucleus of the element. This is something we now take for granted. Before Moseley’s work, the atomic number was seen by many as an ordering number from light to heavy atoms with no obvious significance. When Mendeleev first constructed the periodic table of elements in 1869 (with a revision in 1871), he ordered the elements from lowest to highest atomic mass with several gaps and occasional swaps, *e. g*. cobalt and nickel, to make sure that elements in columns had similar chemical properties.

 Antonius van der Broek suggested, based on Geiger and Marsden’s data of Rutherford scattering of a-particles by metal foils, that the atomic number of an element, rather than atomic mass, is an indicator of the element’s positive nuclear charge ((*Nature*, **92** (1913), 372 f.). Moseley set out to examine this suggestion. His evidence from measurements of the characteristic K and L x-ray wavelengths of 38 elements convinced scientists of the truth of this idea.

Use the data in the Excel spreadsheet “Henry Moseley Data-stu.xlsx” for the calculations below.

**Part A**

1. For the 10 elements in **Part A**, calculate wavelengths *l*2 and *l*3 of the second and third order Ka Bragg spectra from Moseley’s angle measurements.

2. State conclusions you draw from a comparison of the of the two wavelength values.
(Moseley used the *l*3 value in his calculations because it was the brighter of the two orders of the Ka line, scattered at a greater angle, and had less measurement uncertainty.)

3. Calculate wavelength uncertainties that result from Moseley’s 0.1° angle uncertainty.

4. a. As a check on Moseley’s measurement, calculate the energy of the x-ray photons corresponding to the *l*3 wavelength values.

b. Look up, and enter in the spreadsheet, the modern measured value of the Ka photon energies from the Lawrence Berkeley Lab X-ray Data Booklet <https://xdb.lbl.gov>.

[Click the element symbol in the Periodic Table icon on the website opening page.]

c. What is the largest fractional difference (LBL – Moseley)/LBL?

5. Shortly before Moseley’s work, in 1913 Niels Bohr developed a semi-classical theory for the wavelengths of radiation emitted by single electron atoms. Wavelengths (*l*) emitted in transitions between energy state *n*2 and energy state *n*1 for a single electron with negligible mass (*m*e) orbiting an atom with nuclear mass *M* are given by $\frac{1}{λ}=RZ^{2}\left(\frac{1}{n\_{1}^{2}}-\frac{1}{n\_{2}^{2}}\right)$ , where
*R* = Rydberg constant, *Z* =number of positive nuclear charges. The Rydberg constant is
 $R=\frac{q\_{e}^{4}m\_{e}}{8ϵ\_{0}^{2}h^{3}c}=0.010973732 nm^{-1}$,where
 *q*e = elementary charge = 1.602176634 x 10-19 C, *m*e = 9.1093837015 x 10-31 kg,
 *e*0 = 8.854187817 x 10-12 F m-1, *h* = 6.62607015 x 10-34 J s, *c* = 299792458 m s-1.

a. Show that the units of the Rydberg constant are [length]-1.

b. Calculate the Rydberg constant from the fundamental constants given above to verify the value quoted.

6. Make an argument that Moseley’s Q values for the Ka lines should be a good proxy for (*Z -* 1).

7. a. For a finite mass electron (*m*) orbiting a nuclear mass (*M*), the so-called reduced mass of the electron $μ=\frac{1}{\frac{1}{m}+\frac{1}{M}}=m\left(\frac{1}{1+\frac{m}{M}}\right)$ should be used in Bohr’s theory. Calculate $\left(\frac{1}{1+\frac{m}{M}}\right)$ for calcium to show that this correction is negligible for Moseley’s data.

b. EXTRA
 Show (on a separate page) why the reduced mass should be used in Bohr’s theory.

**Part B**

If you have time to work with Moseley’s data in **Part B** of the spreadsheet, continue with the following.

8. a. What trend do you see for (*Z* - *Q*) for the Ka lines of the heavier elements?

 b. Make an argument that the trend is expected.

9. Make an argument that Moseley’s *Q* value for the La line should be a good proxy for approximately (*Z* – 7).

10. **BONUS**
 Which element did Moseley name incorrectly among his list for La line measurements?