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2. Henry Moseley's Law and it's Applications

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ABSTRACT

Henry Moseley, a British physicist, published data in December 1913 and April 1914 that is now recognised as the first experimental evidence for the atomic number as a physical property of the nucleus. Moseley used x-ray spectroscopy to analyse several rare earth elements provided by Georges Urbain shortly after, in June 1914. Moseley died in the First World War before his conclusions were published. Despite his mother's and colleagues' efforts, a posthumous publication never materialised. The archival materials reveal some of the pressures that could have prevented publication, such as Rutherford's unfamiliarity with Moseley's process, but more importantly, the fact that this data would influence the debate over element 72's discovery. Surprisingly, this controversy is likely to have resulted in the retention of relevant archival material. By tracing the actors who created and curated a specific collection of documents and spectra, one can investigate how rare earth knowledge was produced and verified in the early twentieth century.

KEYWORDS:

Moseley's Law, Applications, atomic number, transmission spectra, Rydberg constant, periodic table, Moseley's Law Experiment.

Introduction:

Moseley's law is an empirical law that governs the X-rays emitted by atoms. Henry Moseley, an English physicist, discovered and published the law in 1913-1914.[1][2] Until Moseley's work, "atomic number" was simply an element's position in the periodic table and had not been linked to any measurable physical quantity.[3]

Henry Moseley was not in a celebratory mood when he wrote this letter to his sister on June 7, 1914. It was less than a week after an experiment with the renowned rare earth chemist, George Urbain. They hoped to demonstrate that Urbain's preparation "celtium" was the missing element with the atomic number 72. The data only served to disappoint. After turning the scientific community on its head and putting the elements in their place with two papers on "High-Frequency Spectra of the Elements," Moseley was disappointed by this null result. But it should pique our interest. He used X-ray spectroscopy not only to identify gaps in the known element list, but also to rule out a candidate for one of those gaps. In this International Year of the Periodic Table, consider element 72 before it was known as hafnium, when the prospect of its discovery brought chemists and physicists together in a novel way. [4]

Source: History of Science Museum, University of Oxford

Pl XXIII."Source: History of Science Museum, University of Oxford 24 Chemistry International, April-June 2019Hedof heterogeneous reflected radiation. These distinctive X-rays were associated with the platinum target in their X-ray tube. Moseley then set his sights on investigating the characteristic radiation of a group of elements in the periodic table, which was largely organised by increasing atomic weight and shared chemical properties. He made certain to include two outliers in his study: Co and Ni, whose atomic weights did not fit the overall pattern. He set out to answer the following question: Would the atomic weight or element order in the periodic system determine the X-ray spectra? Moseley used a customised X-ray tube with a trolley of interchangeable elemental targets that he could pull under the tube's cathode in relatively quick succession for his first foray into the 'High-Frequency Spectra of the Elements'. In contrast to his first X-ray study, in which he used an ionisation detector to measure the intensity of the radiation as a function of the angle of reflection, he imaged the spectra with photographic plates. When all of the images were arranged according to the angle of reflection, this captured the strongest two emission lines, but it was enough to create a powerful visual. Unlike the atomic weight, the X-ray data were decisive in placing Ni between Co and Cu. Moseley resigned from his fellowship at Manchester and relocated to the University of Oxford to work as an unpaid researcher in the Electrical Laboratory. He was looking for a new job.

In comparison to Rutherford's frenzy of activity, the Electrical Laboratory moved at a slower pace and had less support staff to help with the construction and repair of his apparatus, which is why Moseley still contracted with the Manchester instrument maker to provide some of the equipment needed for the next phase of his research. Part II, published in April 1914, increased his dataset from 12 to 24 elements to 45. [4]

Review of Literature:

The International Year of the Periodic Table 2019 marked the sesquicentenary of the publication by Dmitri Mendeleev in 1869 of his first version of a periodic table of the elements, ordered in rows and columns on the basis of their atomic weights, now given the symbol A. In the 1869 publication, atomic weight increases monotonically down a given column, while the elements within each row have similar chemical properties. The arrangement of rows and columns was reversed in Mendeleev's later publication of 1871 [5].

Previous attempts to classify chemical elements based on measurable characteristics date back to the turn of the nineteenth century and the work of French chemist Antoine Lavoisier, English chemist John Dalton, and others [6]. In 1862, seven years before Mendeleev's periodic table was published, French geologist Alexander-Emile Beguyer de Chancourtois proposed a 'vis tellurique,' a 45° helix on the outside of a vertical cylinder on which chemical elements were arranged in atomic weight order [7].

Just before the Great War began in 1914, Harry used an electron beam to excite X-rays from nearly 40 elements, including gold ($Z = 79$) [8]. He demonstrated that the square roots of the frequencies of the emitted characteristic radiations could be linked to an ordinal number that defined each element's position in the periodic table. The Bohr-Rutherford model of the nuclear atom was still in its infancy at the time of these pioneering experiments, but Harry immediately recognised that the integer numbers emerging from his experiments had to be the same as the charges on the atomic nuclei within this new model.

However, he was hired as a University Demonstrator in Physics at the University of Manchester, where he worked under the patronage of Ernest Rutherford, the 1908 Nobel Laureate in Chemistry [10]. Harry had a heavy teaching and demonstrating load during his first two years at Manchester, which irritated him. His research, like that of the rest of Rutherford's group, focused on radioactivity—the primary focus of work in Manchester. This research was neither exciting nor challenging for Harry. Nonetheless, his two years of radioactivity resulted in the discovery of an isotope with the shortest half-life ever measured [11] and a record high voltage produced when radium decayed by emission in a vacuum [12]. In the autumn of 1912, he began his research on X-rays, which resulted in a joint experimental paper with Charles Glanton Darwin in May 1913 [13].

Objectives:

- Determining the K absorption edges in Zr, Mo, Ag, and In transmission spectra.
- Confirming Moseley's law.
- Calculating the Rydberg constant.

Research Methodology:

Moseley's law states that "the square root of the frequency of an atom's emitted x-ray is proportional to its atomic number." This law also resulted in the discovery of new elements.

Result and Discussion:

Moseley Law Overview:

Moseley's law is regarded as one of the most significant advances in modern chemistry. It is a physical law developed by English physicist Henry Moseley between 1913 and 1914. This law established the basis for today's periodic table and aided in explaining the behaviour of elements in the universe. According to Moseley's law, an element's atomic number is directly proportional to its nuclear charge, and the order of elements can be explained in terms of their nuclear charge. Moseley's work was groundbreaking in that it helped to explain the mysterious behaviour of elements and filled gaps in Mendeleev's periodic table. In this blog post, we will examine Moseley's law in greater depth, discussing its significance, implications, and impact on the evolution of modern chemistry.

Moseley's Law was discovered thanks to the work of J.J. Thomson and Ernest Rutherford, who discovered the electron and proton, respectively. Using X-ray spectroscopy, Moseley was able to determine the atomic numbers of all elements. He precisely measured the wavelengths of X-rays produced by various elements and used this information to calculate the atomic number of each element.

Moseley's Law Statement

Moseley's Law Statement asserts that:

"The square root of the frequency of x-ray emitted by an atom is proportional to its atomic number."

According to the law,

E (kev) = K (Z - 1)2

Where Z= atomic number

K = 1.042 x 10-2 for K-shell

K = 1.494 x 10-3 for L-shell

and K = 3.446 x 10-4 for M-shell

The effective charge of the nucleus decreases by one when it is screened by an unpaired electron that remains behind in the K-shell.

In any case, here is Bohr's formula for Moseley's K-alpha X-ray transitions:

E = hv

= E - E = mq4 (Z−1)28h2ε2 112 - 122.... (2)

Now, dividing both the sides by ‘h' and converting ‘E' to ‘f' in equation (2), we get:

f = v = (34) mq4 (Z−1)28h2ε2 = (2.48 ∗10Hz (Z - 1) .... (3)

Here, it is necessary to understand that equation (3) is the Moseley equation.

Moseley Law Experiment:

1. The primary building blocks of the X-ray crystallography process are X-ray spectrometers.
2. Moseley's approach to using X-ray spectrometers is as follows:
3. A glass-bulb electron tube was used, and electrons were fired at a metallic object within this evacuated tube, which was a sample of the pure element in his study.
4. Electron ionisation from the element's inner electron shells was caused by firing electrons at a metallic object. The rebound of electrons into the inner shell holes caused X-ray photons to leave the tube in a semi-beam via an aperture in the exterior X-ray shielding.
5. These emitted X-rays were then diffracted by a standardised salt crystal, yielding angular results in the form of photographic lines by exposing an X-ray film mounted at a specific distance outside the vacuum tube.
6. Moseley then applied Bragg's formula to calculate the wavelength of the emitted X-rays after estimating the mean distances between atoms in the metallic crystal based on its density.

Moseley Law Derivation:

So according to Henry Moseley,

We have ν = a (Z–b) … (1)

Assume a transitive state occurs from n1 to n2 according to Bohr's theory. The energy of a photon emitted is

hν = RChz2 (1n21–1n22)

were,

n1 = quantum number of final energy level

n2 = quantum number of initial energy level

ν = frequency for the kα lines

z = Atomic number

$h=6.63*10^{-34}Js$

R = Rydberg constant

C = Constant

Applications of Moseley Law

1. The law resulted in the discovery of new elements such as hafnium (72), technetium (43), rhenium (75), and others.

2. Many inconsistencies were resolved by arranging elements in the periodic table based on Atomic Number rather than Atomic Mass.

Moseley's Law periodic table

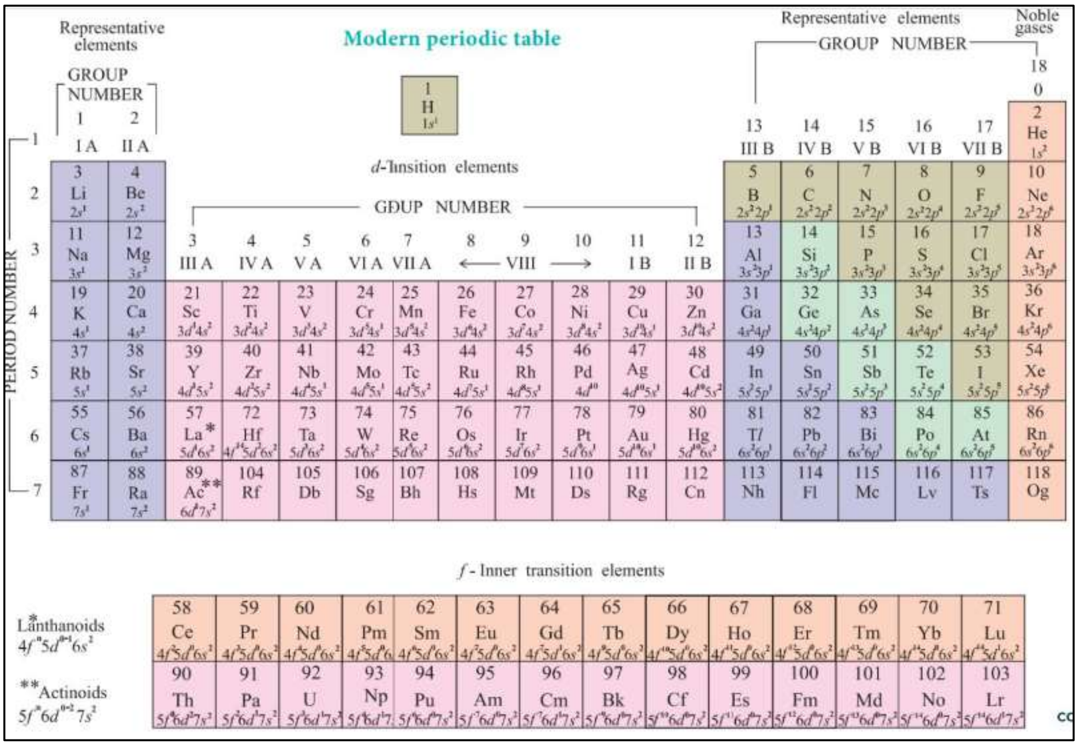
The Moseley periodic table is a significant advancement in the field of chemistry. By introducing the concept of atomic number, it transformed the traditional view of the periodic table.

In contrast to the traditional ordering of elements based on atomic weight, Moseley's table takes into account the number of protons in each atom's nucleus. Because of this elemental arrangement, their chemical properties could be predicted more accurately.

The Moseley periodic table is based on the fact that an atom's atomic number is represented by the number of protons present in its nucleus. This number is one of an element's most important characteristics. The periodic table's arrangement of elements according to their atomic number aids chemists' understanding of the various elements.

This periodic table has proven to be a useful resource in chemistry and physical science research. It has enabled scientists to better understand the properties of elements, which is critical for the advancement of chemistry and physics.

Scientists can now predict the properties of elements and compounds in advance thanks to Moseley's table. It has been a tremendous help in the advancement of modern chemistry and physics.



Importance of Moseley's Law:

Moseley's law is significant because it demonstrates that an element's atomic number is more important than its atomic mass. As a result, rather than atomic mass, the periodic table was reorganised based on atomic number. This law aided in the discovery of new elements and provided a clearer understanding of each element's properties.

Moseley published a paper in 1914 in which he examined three unknown elements in relation to two others. He improved our understanding of how to study elements through his tests and data. He also discovered that the K lines were related to the atomic number and devised a formula to approximate their relationship.

Contributions of Moseley's Law:

While studying the k graphs of various metals, Henry Moseley discovered a link between the k lines and the atomic number. He discovered a straight line when he plotted a graph between the square root of the frequency (denoted by v) of the k lines and the atomic number (Z). Based on his observations, he proposed the formula a(Z-b).

This discovery led to the realisation that the periodic table's arrangement should be based on atomic number rather than atomic mass. Previously, chemists believed that elements should be organised by atomic mass, which resulted in errors such as arranging cobalt (atomic mass = 58.93) before nickel (atomic mass = 58.69). However, when the atomic numbers of cobalt (27) and nickel (28) are considered, the arrangement is correct.

Conclusion:

Soon after Rutherford's scattering hypothesis was validated by experiment (around 1913), Henry Moseley's work reinforced the one-to-one identification of an atomic number Z with each element. (1887- 1915). Bohr proposed the Bohr model of the atom in 1915. It was made possible through the modification of Rutherford's atomic model. Henry Gwyn Jeffreys Moseley/mozli/ (November 23, 1887 – August 10, 1915) was a British physicist who used physical criteria to prove the earlier empirical and chemical concept of the atomic number.

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