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Publications

Open Access
ONLINE ISSN: 2992-5819
PRINT ISSN: 2992-6149

NEWPORT INTERNATIONAL JOURNAL OF SCIENTIFIC AND EXPERIMENTAL SCIENCES (NIJSES)

Volume 5 Issue 2 2024

https://doi.org/10.59298/NIJSES/2024/10.5.26216

Exploring the Trends and Patterns in Periodicity of Elements: from Mendeleev to Modern Periodic Table

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ABSTRACT

Dmitri Mendeleev created the periodic table in 1869, and it has undergone significant modifications to become an essential tool in chemical science today. This abstract provides an informative summary of the evolution of periodic trends and patterns, from Mendeleev's work to the latest complexities in the current periodic table. The first step towards comprehending the periodicity of elements was Mendeleev's periodic table, which he offered as a means of classifying elements according to their atomic weights and chemical behaviours. The periodic table underwent additions and modifications during the ensuing decades as atomic theory and experimental methods advanced. Instead of focusing on atomic weights, the current periodic law is concerned with the precise atomic number. Henry Moseley's discovery of the atomic number altered the elemental positions. This modification allowed for a deeper examination of periodic trends between elements by clarifying elemental relationships. Periodic trend analysis takes into account several characteristics, such as atomic radius, ionisation energy, electron affinity, and electronegativity. This is evident from the fact that each group of elements, ranging from noble gases to alkali metals, has distinct tendencies in both physical and chemical properties. We gathered the necessary materials for this review from a variety of reliable sources, including physical chemistry by K. K. Sharma, inorganic chemistry by J. D. Lee, and other published works. In conclusion, Mendeleev's table's evolution to its current state demonstrates that scientists have been addressing the issue for many generations. The periodic table is still a vital tool for classifying and evaluating the wide range of elements and their characteristics, although there are still many uncharted territories in chemistry.
Keywords: electronic configuration, group analysis, periodic trend, periodicity, atomic number, and quantum physics.

INTRODUCTION

The Periodic Table, a system that aids in accurately classifying the relationships between elements, is one of the most important and often used tools in chemistry [1]. It has been fascinating and transformative to study the periodic table and its evolution, starting with Mendeleev's work in the 1800s and continuing to the present day with the creation of the contemporary periodic table [2]. This has broadened our understanding of the basic elements of matter in our environment and helped to advance scientific research, technological developments, and inventions. Chemistry underwent a revolution when Russian scientist Dmitri Mendeleev published the periodic table in 1869. Mendeleev developed a theory that, by carefully classifying the elements according to their atomic weights and characteristics, he not only brought order to the disorganised chemical elements but also predicted the makeup and characteristics of upcoming elements [2]. His ideas revolutionised the practice of chemistry theory and experiments, laying the groundwork for future studies into the periodicity of elements. Over the ensuing decades, Mendeleev improved his periodic table as theories and experiments advanced. The early twentieth-century discovery of quantum mechanics by great minds like Niels Bohr and Erwin Schrödinger opened up new insights into the electrical structure of atoms and the laws governing their behavior [3]. Because it clarified why some characteristics, like electronegativity, ionisation energy, and atomic size, showed the periodic trends they do, this additional information improved the periodic table's predictability [4]. International scientists and researchers have worked together to create the current periodic table. Scientists have linked it with atomic theory, spectroscopy, computational chemistry, and other fields to create a complex theoretical model that explains the electrical structure, chemical behaviours, and periodic grouping of elements based on atomic number [5]. In addition, the periodic table still functions as a roadmap for the hunt for novel materials, phenomena, and chemicals required for the creation of new kinds of materials. We composed this report by examining the history of scientific advancement that led to the identification of elemental eras. From the work of the Russian scientist Dmitri Mendeleev to the philosophical attempt to explain quantum mechanics, this review explores the trends and patterns that control the actions of atoms in the periodic table. Therefore, by taking this route, we hope to discover not only the significant advancements that have been made but also the numerous chances for discoveries in the domains of chemistry and other sciences.

HISTORICAL PROGRAMMES

Many things have changed since Dmitri Mendeleev created the periodic table in 1869. Before Mendeleev, previous scientists had classified the elements according to various criteria, including atomic weight, chemical reactivity, and physical attributes [2]. In 1864, John Newlands created the Law of Octaves, which declared that components in the eighth position in the series have similar qualities [6]. However, this classification was somewhat restrictive and omitted several ideas that were popular at the time. In 1869, Dmitri Mendeleev created the first widely recognised version of the periodic table. Mendeleev's suggestion grouped elements based on their chemical similarities and arranged them in ascending order of atomic weight [7]. Based on the qualities of the neighbouring element, Mendeleev left vacant spaces in his chart for some of the undiscovered elements, based on plausible assumptions about them [8]. The discovery of elements like gallium, scandium, and germanium, which were discovered much later but previously predicted by Mendeleev's periodic table, essentially confirms this viewpoint [9]. While the electron is the most well-known subatomic particle, J. J. Thomson discovered several others at the beginning of this century. In 1897, Thomson discovered the atom's nature [10]. Ernest Rutherford, using the gold foil experiment, attempted to identify the atomic nucleus in 1909 and concluded that the nucleus contains the majority of an atom's mass [11]. His X-ray spectroscopy of the elements in 1913 credits Henry Moseley with creating the idea of an atomic number. At that time, this number determined the arrangement of the elements in the present periodic table. Unlike its previous iteration, the current periodic table arranges the elements based on their atomic number, or the number of protons in their nucleus [12]. Therefore, this configuration more accurately represented the periodicity of elements, better matching the periodic recurrence of chemical properties. It is also important to remember that the modern periodic chart includes the ideas of groups (columns) and periods (rows) [13]. Because the elements in a group have similar electron configurations, their chemical properties are comparable. In the 1920s, the Schrödinger equation served as the primary means of applying quantum mechanics to explain the behaviour of electrons within an atom [14]. Quantum physics explains the propensity of elements by stating that members of the same group have similar numbers of outer shell electrons and, thus, display similar chemical behaviours [3]. The knowledge of chemical elements has expanded with the discovery of new elements and their addition to the current periodic table. Technological advancements, mainly in the areas of spectroscopy and particle accelerators, have led to the discovery and synthesis of additional elements beyond those Mendeleev mentioned in his initial table [15]. Overall, the evolution of the periodic table has shifted from actual observation-based classifications to current knowledge based on quantum physics and atomic theory. Despite this small flaw, it is still a useful tool in chemistry for classifying and forecasting elemental characteristics.

PERIODIC TREND AND PATTERN

Periodic trends and patterns refer to the systematic variations in an element's properties as one moves through the groups (or columns) and periods (or rows) of the periodic table [16]. These patterns are caused by the distribution of electrons within atoms, which impacts ionisation, electron gain, or electronegativity, among other associated features. Understanding these patterns aids in forecasting the conduct of the components and their amalgamations, as well as providing insight into chemical reactivity and bonding. Information on atomic size reveals that, throughout time, atomic size decreases from left to right [17]. As the nuclear charge increases, it draws the outermost electrons closer to the nucleus. Generally speaking, the atomic radius tends to grow in a group. The reason for this is that the outermost electrons are becoming farther and farther away from the nucleus with each addition of an electron shell. It is a known fact that ionisation energy typically grows from left to right over a specific period [18]. This is because removing electrons becomes increasingly difficult as time progresses, leading to a corresponding increase in the effective nuclear charge. Reversing a period from left to right typically results in an energy reduction. This is because the atom's nucleus attracts electrons at a significantly higher energy level. Over the periodic table, electron affinity density typically falls until it reaches noble gases, when it becomes increasingly negative (exothermic) [19]. Elements on the right side of the periodic table typically exhibit higher electron affinities. Decending a group typically results in a decrease in electron affinity. Electronegativity typically increases in a left-to-right direction across the periodic table [20]. Since atoms with larger effective nuclear charges also have higher electronegativities, this is not the only explanation. In general, electronegativity tends to decrease with group membership. An atom's ability to attract electrons explains this; as an atom grows bigger, the attraction towards its valence electrons decreases due to the distance between its nucleus and them. Elements on the left side of the periodic table exhibit a progressive shift in metallic character towards those on the right, in this order. This is because, as time passes, the atoms' atomic sizes decrease and their ionisation energies increase, resulting in an increase in non-metals and a decrease in metals [21]. As you progress through a group, the metallic character becomes more prominent. Metals, composed of larger atoms, possess more valence electrons due to their separation from the nucleus. As the group's atom size decreases, the number of electrons in the outermost shell, which are readily lost to create positive ions, increases, accounting for the increasing reactivity of metals. As we move down the group, reactivity with non-metals decreases and rises from right to left. The periodic table arranges the elements in groups or columns based on their chemical similarities. This eventually results in families or clusters of noble gases, halogens, alkali metals, and alkaline earth metals. Because an element's outer electrons are relatively similar, chemical processes within the same group tend to move similarly. Periodic trends and patterns not only characterise and evaluate the results of chemical experiments but also forecast the makeup and behaviour of individual elements. They provide a framework for organising a diverse range of chemical ingredients into a logical and forecasting system.

Collective Grouping of the Periodic Table

The periodic table's group-wise classification emphasises the elemental arrangement based on vertical columns, also referred to as groups or families. Because all of these groups contain the same number of valence electrons, which are the electrons at the highest energy level, they have the same chemical characteristics [22].

Alkali metals (Group 1) according to [23].

i. Alkali metals include, among others, sodium (Na), lithium (Li), and potassium (K).
ii. Due to their extreme reactivity, we typically keep these metals submerged in oil to shield them from the moisture in the surrounding air.
iii. They are more than willing to shed their single valence electron to produce positive ions.
iv. They share chemical characteristics, such as the creation of a strong base and the development of hydrogen gas when they interact with water in hydroxide ion reactions.

Alkaline Earth Metals (Group 2) in accordance with [24].

i. Among the alkaline earth metals are beryllium (Be), magnesium (Mg), and calcium (Ca).
ii. Although not as reactive as the alkali metals, they are still considered extremely reactive.
iii. They have two valence electrons and can easily form +2 charge cations.
iv. They often exhibit a white, glossy, metallic luster.

Metal Transitions (Groups 3–12) as reported by [25].

i. Among other transition metals are copper (Cu), iron (Fe), and gold (Au).
ii. The way their d-orbital fills change with the introduction of electrons over time sets them apart.
iii. Transition metals frequently exhibit numerous oxidation levels and produce complicated structures.
iv. Their high melting and boiling points, as well as their capacity to synthesise a wide range of ions and compounds, are widely known.

Chalcogens (Group 16) according to [26].

i. Chalcogens are defined as elements like oxygen (O), sulphur (S), and selenium (Se), among others.
ii. They possess six valence electrons and are capable of producing -2 ions with ease
iii. Chalcogens play a crucial role in life processes and are present in a wide range of significant physiological agents.

Halogens (Group 17) as stipulated by [27].

i. This group of elements includes, among other elements, iodine (I), fluorine (F), chlorine (Cl), and bromine (Br).
ii. These elements have seven electrons in their outermost shell and easily form -1 ions.
iii. Halogens, highly reactive non-metals, are commonly found in salt solutions.
iv. As you move down the group or across the table horizontally, they become less reactive.

Noble Gases (Group 18) as written [28].

i. Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn) are a few examples of noble gases.
ii. They are extremely stable and chemically inert because they consist of full numbers of atomic orbits.
iii. Lighting applications, like neon lamps, frequently use noble gases in inert gaseous environments.

To improve comprehension of the chemical behaviour of the element in question, this group-wise analysis focuses primarily on the similarities and differences in the properties of elements that belong to a given group.

PERIODICITY AND QUANTUM MECHANISMS

In the context of quantum mechanics, periodicity primarily refers to the properties of periodic molecules and atoms [29]. The periodic table of elements is a well-known system of classifying elements based on their atomic number, electron arrangement, and recurring chemical properties. The idea of periodicity originates from Schrödinger's equation, which depicts the probability distribution of the electrons surrounding the nucleus [30]. This formula produces a spectrum of allowed energy levels, each associated with a specific quantum state or orbital. Because the energy levels are quantized, they can only take a very small number of discrete values [31]. But this idea starts to make more sense, particularly when looking at the atoms in the next groupings that have a lot of electrons besides hydrogen. However, chemistry experts have demonstrated through experimental results and theoretical knowledge that electron variation in shells and subshells surrounding an element's nucleus causes periodicity in atomic properties like ionisation energy, atomic radius, and electron affinity [13]. The periodic table organically arranges elements based on their electron configurations, arranging periods in horizontal rows and groups (or families) in vertical columns. Certain elements within a group have comparable chemical properties due to nearly identical electronic configurations, whereas elements within the same period have identical electron shells [32]. Many other areas of quantum mechanics and solid-state physics also utilize periodicity. For example, in solid crystals, electrons experience a periodic potential, which leads to the production of energy bands and band gaps, which are important for understanding electrical characteristics in materials science. Understanding material properties, atomic and molecule configurations, and both requires a thorough understanding of quantum mechanics' idea of periodicity.

APPLICATIONS AND EXTENSIONS THE PERIODIC TABLE

Many practical applications, as well as the sciences, use the periodic table as a vital resource for understanding elements and their characteristics [33]. It offers a structure for formulating experimental plans and forecasting chemical reactions. In the field of material science, it directs the synthesis of materials with particular characteristics [34]. The understanding of elements and their compounds forms the foundation of pharmacology and drug discovery principles [35]. Environmental studies employ it to estimate pollution levels and forecast the effects of pollutants on ecosystems [36]. It enables elements in nuclear chemistry to be arranged according to how stable and radioactive they are. We modify the table to accommodate newly discovered or synthesized elements. Furthermore, it provides insight into the electronic structure of atoms and molecules, making it essential to theoretical chemistry. The periodic table's structure and periodicity are beneficial to the metallurgical, electrical, power, and agricultural industries [37]. The Periodic Table's Future The periodic table systematically arranges all recognized elements based on their atomic numbers, electron configurations, and chemical properties. But much of the talk and concern centers on its possibilities and future. The periodic table currently lists Oganesson, (Og), but scientists are working to synthesize even heavier elements. According to theoretical research, there might be a superheavy element "island of stability" where specific proton and neutron combinations lead to comparatively stable underlying nuclei [38]. Researchers are investigating the connection between the atomic chart and nonconventional forms of matter, such as quark-gluon plasma. Future studies in material science and technology may benefit from the production of stable or long-lived isotopes through the nuclear fusion of synthetic elements in particle accelerators to produce stable or long-lived isotopes [39]. For a more comprehensive understanding of the relationships between various components, subsequent iterations may incorporate other dimensions, such as electrical, magnetic, or optical qualities. Advances in theoretical chemistry and quantum mechanics enhance our understanding of atomic and molecular structure [40].

CONCLUSION

In conclusion, the development of the periodic table from Mendeleev's original design to its current configuration is a fascinating tale of scientific advancement and discovery. Mendeleyev's work and significant advancements in atomic theory and quantum physics have enhanced our understanding of the nature of matter. Despite using a structural method to arrange elements according to their atomic properties, experts in a variety of sectors, such as chemistry, material science, medicine, and the environment, continue to find value in the periodic table. In the early stages of further scientific investigation, the periodic table continues to be a helpful tool for organizing the vast array of elements and pointing out new directions in scientific understanding. It is certain that subsequent attempts to extend the periodic table, investigate new forms of matter, and delve further into the study of atomic and molecular interactions will lead to even more discoveries and insights in the future. Thus, the periodic table continues to stand as a testament to the human spirit and its insatiable curiosity, guaranteeing its continued relevance for many centuries to come.

REFERENCES

1. Periodic table | Definition, Elements, Groups, Charges, Trends, & Facts | Britannica, https://www.britannica.com/science/periodic-table
2. A brief history of the periodic table, https://www.asbmb.org/asbmb-today/science/020721/a-brief-history-of-the-periodic-table
3. Arvind, A., Dorai, K., Chaturvedi, S., Mukunda, N.: The Development of Quantum Mechanics: A Story of People, Places and Philosophies. Resonance. 23, 1077–1100 (2018). https://doi.org/10.1007/s12045-018-0715-y

Open Access
ONLINE ISSN: 2992-5819
PRINT ISSN: 2992-6149

4. Periodic Trends, https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_and_Websites_(Inorganic_Chemistry)/Descriptive_Chemistry/Periodic_Trends_of_Elemental_Properties/Periodic_Trends
5. History of atomic theory, https://en.wikipedia.org/w/index.php?title=History_of_atomic_theory&oldid=1225294879, (2024)
6. Newland's Law of Octaves: Definition, Examples, and FAQs, https://www.geeksforgeeks.org/newlands-law-of-octaves/
7. How did Mendeleev create and invent the periodic table of chemical elements?, https://www.quora.com/How-did-Mendeleev-create-and-invent-the-periodic-table-of-chemical-elements
8. Campbell, C., Pulkkinen, K.: How Mendeleev issued his predictions: comment on Andrea Woody. Found Chem. 22, 197–215 (2020). https://doi.org/10.1007/s10698-020-09355-7
9. Orna, M., Fontani, M.: Discovery of Three Elements Predicted by Mendeleev's Table: Gallium, Scandium, and Germanium. Presented at the July 1 (2021)
10. Sir George Paget Thomson | Biography, Nobel Prize, Electron Diffraction | Britannica, https://www.britannica.com/biography/J-J-Thomson
11. The Structure of the Atom | Texas Gateway, https://www.texasgateway.org/resource/221-structure-atom
12. The modern periodic table - The periodic table - Edexcel - GCSE Chemistry (Single Science) Revision - Edexcel, https://www.bbc.co.uk/bitesize/guides/zxmmsrd/revision/2
13. Periodic table, https://en.wikipedia.org/w/index.php?title=Periodic_table&oldid=1226292566, (2024)
14. Quantum Mechanics, Interpretations of | Internet Encyclopedia of Philosophy, https://iep.utm.edu/int-qm/
15. Türler, A., Pershina, V.: Advances in the Production and Chemistry of the Heaviest Elements. Chem. Rev. 113, 1237–1312 (2013). https://doi.org/10.1021/cr3002438
16. Periodic Trends, https://shiken.ai/chemistry/periodic-trends
17. High School Chemistry/Atomic Size - Wikibooks, open books for an open world, https://en.wikibooks.org/wiki/High_School_Chemistry/Atomic_Size
18. Ionization energy, https://en.wikipedia.org/w/index.php?title=Ionization_energy&oldid=1223817068, (2024)
19. Electron Affinity, https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/Atomic_and_Molecular_Properties/Electron_Affinity
20. Electronegativity - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/chemistry/electronegativity
21. Helmenstine, A.: Metallic Character Trend on the Periodic Table, https://sciencenotes.org/metallic-character-trend-on-the-periodic-table/, (2021)
22. Families and Periods of the Periodic Table, https://chem.libretexts.org/Courses/Valley_City_State_University/Chem_121/Chapter_2%3A_Atomic_Structure/2.03%3A_Families_and_Periods_of_the_Periodic_Table
23. Hydrogen and the Alkali Metals, https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_and_Websites_(Inorganic_Chemistry)/Descriptive_Chemistry/Elements_Organized_by_Block/1_s-Block_Elements/Group__1%3A_The_Alkali_Metals
24. Alkaline Earth Metals: Definition, Properties, Use, and Types, https://www.xometry.com/resources/materials/alkaline-earth-metals/
25. General Trends among the Transition Metals, https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_and_Websites_(Inorganic_Chemistry)/Descriptive_Chemistry/Elements_Organized_by_Block/3_d-Block_Elements/1b_Properties_of_Transition_Metals/General_Trends_among_the_Transition_Metals
26. Chalcogen, https://en.wikipedia.org/w/index.php?title=Chalcogen&oldid=1214870237, (2024)
27. Halogen, https://en.wikipedia.org/w/index.php?title=Halogen&oldid=1224079483, (2024)
28. Noble Gases - Group 18 of the periodic table, which includes #helium (He), #neon (Ne), #argon (Ar), #krypton (Kr), #xenon (Xe), #radon (Rn), and other naturally occurring gases, is known as the noble gases (historically also the inert gases, sometimes referred to as #aerogens.,

29. Quantummechanics, https://en.wikipedia.org/w/index.php?title=Quantum_mechanics&oldid=1222618175, (2024)
30. Schrodinger Wave Equation - Definition, Derivation, Significance, https://byjus.com/jee/schrodinger-wave-equation/
31. EnergyQuantization, https://phys.libretexts.org/Courses/University_of_California_Davis/UCD%3A_Physics_7C_-_General_Physics/9%3A_Quantum_Mechanics/9.3%3A_Energy_Quantization
32. Electron Configurations, Valence Electrons, and the Periodic Table, https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Structure_and_Properties_(Tro)/04%3A_Periodic_Properties_of_the_Elements/4.04%3A_Electron_Configurations_Valence_Electrons_and_the_Periodic_Table
33. The History, Relevance, and Applications of the Periodic System in Geochemistry | Request PDF, https://www.researchgate.net/publication/335840359_The_History_Relevance_and_Applications_of_the_Periodic_System_in_Geochemistry
34. Materials Science | AMERICAN ELEMENTS ®, https://www.americanelements.com/materials-science
35. Lincoln, U. of: Chemistry for Drug Discovery and Development | BSc (Hons) | University of Lincoln, https://www.lincoln.ac.uk/course/chmdrgub/
36. Wu, M., Zhan, Y., Liu, Y., Tian, Y.: Evaluation of the Effects of the Ecological Environmental Damage Compensation System on Air Quality. Forests. 13, 982 (2022). https://doi.org/10.3390/f13070982
37. Nonmetal, https://en.wikipedia.org/w/index.php?title=Nonmetal&oldid=1226568753, (2024)
38. Holmbeck, E.M., Sprouse, T.M., Mumpower, M.R.: Nucleosynthesis and observation of the heaviest elements. Eur. Phys. J. A. 59, 28 (2023). https://doi.org/10.1140/epja/s10050-023-00927-7
39. Durante, M., Golubev, A., Park, W.-Y., Trautmann, C.: Applied nuclear physics at the new high-energy particle accelerator facilities. Physics Reports. 800, 1–37 (2019). https://doi.org/10.1016/j.physrep.2019.01.004
40. Quantum Chemistry and the Quantum Revolution. In: ResearchGate

CITE AS: Benedict Nnachi Alum (2024). Exploring the Trends and Patterns in Periodicity of Elements: from Mendeleev to Modern Periodic Table. NEWPORT INTERNATIONAL JOURNAL OF SCIENTIFIC AND EXPERIMENTAL SCIENCES, *5*(2):1-6. https://doi.org/10.59298/NIJSES/2024/10.5.26216