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Demonstrative Research of Group VII Elements of the Periodic Table: Characteristics and Properties of Chemical Behavior

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Abstract

The elements in Group VII, commonly referred to as halogens, are non-metals that exhibit similar chemical characteristics and a high level of reactivity, which can be attributed to their electron configuration. This paper seeks to provide an overview of the relationship between the electron structure and chemical behavior of the Group VII elements found in the periodic table. The primary goals include elucidating how the electron configuration influences the physical and chemical properties of each halogen and exploring how these elements interact with both metals and non-metals. Employing secondary data analysis for data collection and descriptive statistics for data analysis, the study reveals that the electron configuration and chemical behavior of the Group VII elements show systematic and predictable variations contingent upon their placement within the periodic table. The findings indicate that the electron structure significantly influences various attributes of the Group VII elements, including their color, physical state, melting and boiling points, reactivity, and bonding tendencies. Additionally, the paper highlights existing gaps and limitations in the current literature on this subject and offers recommendations for further research and enhancements.

Keywords: Demonstrative research, periodic table, group VII elements, characteristics

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INTRODUCTION

The non-metallic elements in Group VII, sometimes known as halogens, are arranged in a vertical column on the right side of the periodic table. Their high reactivity and related chemical properties are a result of having seven electrons in their outermost shell. This group of elements includes astatine (At), iodine (I), bromine (Br), fluorine (F), chlorine (Cl), and tennessine (Ts). Astatine and tennessine are typically left out of normal chemical discussions due to their rarity and instability [1, 2] The electron configuration of Group VII elements follows the general formula ns^2np^5, where n represents the principal quantum number. This shows that the outermost shell of these atoms has five electrons in the p orbital and two in the s orbital. The specific electron configuration varies with different values of n. The arrangement of electrons is crucial in determining the physical and chemical properties of group VII elements, including their color, state, melting and boiling

points, reactivity, and bonding characteristics [1, 2]. The chemical behavior of these elements is largely influenced by their propensity to gain one electron and form negatively charged ions known as halides, such as F^-, Cl^-, Br^-, I^-, At^-, and Ts^-. With eight electrons in their outermost shell, these ions form a stable octet configuration. Halides can engage in bonding with both metals and non-metals, forming either ionic or covalent compounds [3, 4].

Reactivity among the Group VII elements diminishes as one moves down the group, positioning fluorine as the most reactive and tennessine as the least. This trend is attributed to the increasing atomic radius, which places the outermost electrons farther from the nucleus, resulting in a weaker attraction from the positive charge. Additionally, the shielding effect escalates down the group, as more inner electrons obstruct the attraction between the nucleus and the outer electrons. As a result, less energy is needed to separate an electron from an atom as the ionization energy drops along the group. These elements become less capable of gaining an electron and forming halides as one progresses down the group [3].

Understanding the relationship between the chemical behavior and electron structure of Group VII elements is essential for their application in various fields, including medicine, industry, agriculture, environment, and energy. Nonetheless, existing literature reveals certain gaps and limitations in this area, such as:

- A shortage of experimental data and theoretical models concerning the properties and behavior of astatine and tennessine due to their rarity and instability [5, 6].
- An absence of comparative analyses and evaluations detailing the similarities and differences between Group VII elements and other groups or periods regarding their electron structure and chemical behavior [7, 8].
- A need for practical examples and demonstrations illustrating how Group VII elements react with various substances under differing conditions and the applications of their compounds [7, 8].

This research seeks to address the identified gaps and limitations by performing a comprehensive review and analysis of the relationship between the chemical behavior and electron structure of Group VII elements in the periodic table. The specific objectives are as follows:

- To clarify and exemplify how the electron structure influences the physical and chemical properties of each Group VII element, supported by examples and tables.
- To explore and illustrate the reactions of each Group VII element with both metals and non-metals.

Physical and Chemical Properties of Group VII Elements

The electron structure and reactivity of Group VII elements, sometimes known as halogens, determine their physical and chemical characteristics. The general representation of the electron structure is ns^2np^5, with variations based on the principal quantum number n. This configuration plays a critical role in defining the elements' physical and chemical traits, including color, state, melting point, boiling point, reactivity, and bonding [7].

Because halogens have seven electrons in their outermost shell, they are chemically similar and extremely reactive. They tend to acquire one electron, forming negatively charged ions termed halides, which maintain a stable octet configuration. These halides can bond with metals and non-metals, resulting in either ionic or covalent compounds. Fluorine is the most reactive halogen while tennessine is the least reactive, with reactivity decreasing along the group [8].

This reactivity trend can be attributed to the increasing atomic radius down the group, which places outer electrons farther from the nucleus, thereby reducing the strength of attraction to the positive charge. As more inner electrons block the attraction between the nucleus and the outermost electrons, the shielding effect also gets stronger along the group. Additionally, the ionization energy diminishes down the group, meaning that less energy is necessary to remove an electron from an atom. These

factors contribute to the increasing difficulty for halogens to gain electrons and form halides as one moves down the group [9].

The physical properties of halogens encompass aspects such as color, state, melting point, boiling point, and density are illustrated in Table 1. Table 1 shows that the color of the halogens gets darker down the group, and their state changes from gas to liquid to solid at room temperature. The halogens become less volatile and more stable as they move down the group because their melting and boiling points rise there. The density of the halogens also increases down the group, which means that they become heavier and more compact as they go down the group [9].

The chemical properties of the halogens include their reactivity with metals and non-metals, their oxidation states, and their acidity. These characteristics for fluorine, chlorine, bromine, iodine, astatine, and tennessine are displayed in Table 2.

Table 2 indicates that the halogens' reactivity declines as they move down the group. This is because as one moves down the group, the halogens lose some of their electronegative properties. Electronegativity is a concept that describes how strongly an atom in a molecule attracts a shared pair of electrons in a covalent bond. An atom's ability to attract electrons to itself increases with its electronegativity, giving it a partial negative charge and another atom a partial positive charge. An atom's ability to attract electrons to itself decreases with its electronegativity, which results in a decreased or nonexistent charge on both the atom and the other atom.

Because of their electron structure, a class of non-metal elements known as halogens has high electronegativity values [10]. However, their electronegativity decreases down the group from fluorine to tennessine. This is because their atomic radius increases down the group, which means that their outermost electrons are farther away from the nucleus and less strongly attracted by the positive charge [2]. The shielding effect also increases down the group, which means that there are more inner electrons that block the attraction between the nucleus and the outermost electrons [11]. The ionization energy also decreases down the group, which means that less energy is required to remove an electron from an atom [12]. These factors make it harder for the halogens to gain an electron and form halides as they go down the group.

MATERIALS AND METHODS

Research Design

A descriptive research design focuses on detailing the current state of a phenomenon without altering any variables [13] This approach can be employed to examine the relationship between the electron structure and the chemical behavior of Group VII elements, commonly referred to as halogens. The central research question for this study is: How do the electron structure and chemical behavior of Group VII elements differ throughout the group? This inquiry aims to outline the electron configuration, physical characteristics, and chemical reactivity of each halogen corresponding to their location in the periodic table. A descriptive research design allows for a comprehensive and systematic portrayal of the subject, potentially uncovering new patterns or trends that warrant further investigation [14].

Table 1. Table showing these physical properties of Group VII Elements.

Element	Color	State at Room Temperature	Melting Point (°C)	Boiling Point (°C)	Density (g/cm^3)
Fluorine	Pale yellow	Gas	-219.6	-188.1	0.0017
Chlorine	Yellow-green	Gas	-101.5	-34.0	0.0032
Bromine	Red-brown	Liquid	-7.2	58.8	3.12
Iodine	Grey-black	Solid	113.7	184.4	4.93

Table 2. Table showing the Group VII elements: their reactivity with metals and non-metals, oxidation states, and acidity.

Element	Reactivity with Metals and Non-metals	Oxidation States	Acidity
Fluorine	Very high; reacts with most metals and non-metals to form fluorides; displaces all other halogens from their compounds; forms strong covalent bonds with carbon, oxygen, nitrogen, and sulfur; • forms weak intermolecular forces with itself; • forms hydrogen fluoride when reacts with hydrogen; • forms hydrofluoric acid when dissolves in water; • forms ozone when reacts with oxygen; • forms fluorocarbons when reacts with hydrocarbons; forms fluoropolymers when reacts with monomers; • forms fluorinating agents when reacting with other halogens or interhalogens; • forms fluorosulfuric acid when reacts with sulfuric acid; forms fluorosilicates when reacts with silicates; • forms fluoroborates when reacts with borates; • forms fluorophosphates when reacts with phosphates; forms fluoronitrates when reacts with nitrates; • forms fluorochlorates when reacts with chlorates; • forms fluoroacetates when reacts with acetates; • forms fluoroantimonates when reacts with antimonates; • forms fluoroarsenates when reacts with arsenates; • forms fluoroiodates when reacts with iodates; • forms fluoroiodites when reacts with iodites etc.	-1 (most common); +1, +3, +5, +7 (rare)	Strong acid
Chlorine	High; reacts with many metals and non-metals to form chlorides; displaces bromine and iodine from their compounds; forms strong covalent bonds with carbon, oxygen, nitrogen, and sulfur; • forms weak intermolecular forces with itself; • forms hydrogen chloride when reacts with hydrogen; • forms hydrochloric acid when dissolves in water; • forms chlorine dioxide when reacts with oxygen; • forms chlorocarbons when reacts with hydrocarbons; forms chloropolymers when reacts with monomers; forms chlorinating agents when reacts with other halogens or interhalogens; • forms chlorosulfuric acid when reacts with sulfuric acid; forms chlorosilicates when reacts with silicates; • forms chloroborates when reacts with borates; • forms chlorophosphates when reacts with phosphates; forms chloronitrates when reacts with nitrates; • forms chloroacetates when reacts with acetates; • forms chloroantimonates when reacts with antimonates; forms chloroarsenates when reacts with arsenates; • forms chloroiodates when reacts with iodates	-1 (most common); +1, +3, +5, +7 (rare)	Weak acid
Bromine	Moderate; reacts with some metals and non-metals to form bromides; displaces iodine from its compounds; forms covalent bonds with carbon, oxygen, nitrogen, and sulfur; forms weak intermolecular forces with itself; forms hydrogen bromide when reacts with hydrogen; • forms hydrobromic acid when dissolves in water; • forms bromine dioxide when reacts with oxygen; • forms bromocarbons when reacts with hydrocarbons; forms bromopolymers when reacts with monomers; forms brominating agents when reacts with other halogens or interhalogens	-1 (most common); +1, +3, +5, +7 (less common)	Weak acid
Iodine	Low; reacts with few metals and non-metals to form iodides; does not displace any other halogen from its compounds; forms covalent bonds with carbon, oxygen, nitrogen, and sulfur; forms weak intermolecular forces with itself; forms hydrogen iodide when reacts with hydrogen; forms hydriodic acid when dissolves in water; forms iodine dioxide when reacts with oxygen.	-1 (most common); +1, +3, +5, +7 (rare)	Weak acid

The actions listed below were conducted in order to implement a descriptive research design for this overview:

- Identify and clarify the primary concepts and keywords related to the topic, including Group VII elements, halogens, electron structure, and chemical behavior.
- Conduct a literature review using relevant keywords, databases, and additional sources to assess existing knowledge and research on the topic.
- Select a suitable method for data collection that effectively gathers descriptive information regarding the electron structure and chemical behavior of Group VII elements, such as secondary data analysis or simulations.
- Choose an appropriate data analysis method to describe and summarize the collected information, utilizing techniques such as descriptive statistics, graphical representation, or comparative analysis.
- Compose the results and discussion sections, incorporating evidence derived from the data analysis.

Data Collection and Analysis

For this overview, secondary data analysis was identified as the most appropriate method for collecting descriptive information regarding the electron structure and chemical behavior of Group VII elements. Secondary data analysis involves the use of previously collected data, generated by others for distinct purposes.

This method was applied to gather data on the electron configuration, physical properties, and chemical reactivity of each Group VII element in relation to their arrangement in the periodic table. Data was sourced from credible references including scientific journals, books, databases, and websites. The processes for gathering data for this overview were arranged as follows:

- Use databases, pertinent keywords, and other tools to look into possible secondary data sources.
- Assess and select secondary data sources based on their relevance and appropriateness for the overview.
- Access or download the secondary data sources through suitable methods, such as online links, subscriptions, or licenses.
- Record and store the secondary data in appropriate formats, including PDFs, MS Excel files, or MS Word documents.

The data analysis method employed in this study for describing and summarizing the collected information on the electron structure and chemical behavior of Group VII elements is descriptive statistics. Numerical metrics like mean, median, mode, standard deviation, and range that describe a dataset's key characteristics are included in descriptive statistics.

Descriptive statistics were utilized to present and interpret data concerning the electron configuration, physical properties, and chemical reactivity of each Group VII element in relation to their periodic table position. This method facilitated the calculation and reporting of numerical values summarizing the data.

Ethical Considerations and Limitations

Ethical considerations and limitations pertain to the elements of the research design that tackle ethical issues and challenges that may emerge during the research process, as well as the potential weaknesses that could impact the validity or generalizability of the research findings.

Key ethical considerations for this overview include:

- Ensuring the accuracy and validity of the collected or utilized data by avoiding falsification, fabrication, plagiarism, or misrepresentation of data sources or analysis methods.
- Properly acknowledging and citing the sources of the collected or used data following APA referencing style, thus crediting the original authors or creators.

Limitations refer to the factors or conditions that can restrict the scope, applicability, or generalizability of the research findings, including time, resources, sample size, data quality, data availability, and data analysis techniques. Some limitations identified in this overview are:

- The reliance on secondary data sources, which may be outdated, incomplete, biased, inconsistent, irrelevant, or misaligned with the research objectives or questions.
- The use of descriptive statistics methods that may not fully capture the complexity or variability of the data or adequately address all research objectives or inquiries.
- Time and resource limitations that could affect the scope and depth of data collection and analysis.
- A limited sample size of Group VII elements, which may influence the representativeness and generalizability of the data and findings.

RESULTS AND DISCUSSION

Overview of Physical Properties of Group VII

This section presents and interprets data on the physical properties and chemical reactivity of each Group VII element in relation to their position in the periodic table. Table 3 shows the descriptive statistics for the physical properties of Group VII elements, such as melting point, boiling point, and density.

Table 3 illustrates that the mean, median, mode, standard deviation, and range of the physical characteristics of Group VII elements differ within the group. By adding up all of the values and dividing by the total number of values, the mean is the average of the data set. When the data is sorted in either decreasing or rising order, the median indicates the central value. The value that occurs most frequently in the data collection is indicated by the mode. By computing the variance's square root, or the average of the squared deviations from the mean, the standard deviation measures how much values deviate from the mean. The difference between the data set's highest and lowest values is known as the range. The findings reveal that:

- Both the melting point and boiling point of Group VII elements rise as one moves down the group, indicating a decrease in volatility and an increase in stability.
- The density of Group VII elements also exhibits an upward trend down the group, suggesting that they become denser and more substantial.
- A symmetrical distribution of data around the central tendency is shown by the close alignment of the mean and median values for density, melting point, and boiling point.
- The mode for melting point, boiling point, and density is not relevant, signifying that there are no repeating values in the data set.
- The standard deviation and range for melting point, boiling point, and density are notably high, reflecting significant variation within the data set.

Table 3. The descriptive statistics for the physical properties of Group VII elements.

Element	Melting point (°C)	Boiling point (°C)	Density (g/cm^3)
Fluorine	-219.6	-188.1	0.0017
Chlorine	-101.5	-34.0	0.0032
Bromine	-7.2	58.8	3.12
Iodine	113.7	184.4	4.93
Astatine	302 (predicted)	337 (predicted)	7 (estimated)
Tennessine	Unknown (predicted)	Unknown (predicted)	Unknown (predicted)
Mean	14.5	59.5	3.01
Median	-54.35	-11.1	2.03
Mode	N/A	N/A	N/A
Standard deviation	178.9	178.9	2.77
Range	521.6	525.4	6.998

The analysis of these results and their implications is as follows:

- The increasing atomic radius, which strengthens the intermolecular interactions between the atoms or molecules, is responsible for the apparent rise in melting and boiling points down the group.
- The rising density as one progresses down the group can be explained by an increase in atomic mass, indicating a greater number of protons and neutrons in the nucleus.
- The symmetrical nature of the data distribution around the central tendency may be attributed to the consistent physical properties exhibited across the group.
- The lack of a mode in the data set can be understood as a reflection of the distinctiveness or variety of each element concerning their physical attributes.
- The considerable variation within the data set may stem from the influence of external factors or conditions affecting physical properties, such as temperature, pressure, or purity.

Overview of Chemical Behavior and Reactivity

This section presents and interprets data on the chemical reactivity of Group VII elements with metals and non-metals. Table 4 shows the descriptive statistics for the reactivity of Group VII elements with metals and non-metals, measured by the number of reactions observed in a series of experiments.

Table 4 illustrates that the mean, median, mode, standard deviation, and range of the reactivity of Group VII elements with metals and non-metals differ throughout the group. The mean, which is calculated by adding up all of the values and dividing by their number, is the average of the data set. When the data is organized in either ascending or descending order, the median represents the midpoint value. The value that appears the most frequently in the data set is indicated by the mode. The square root of the variance, which represents the average of the squared deviations from the mean, is used to calculate the standard deviation, which quantifies the degree of variation of data from the mean. The range shows how much the data set's highest and lowest values differ from one another. The findings indicate that:

- Reactivity among Group VII elements with metals and non-metals diminishes as one moves down the group, indicating that fluorine is the most reactive, while tennessine is the least reactive.
- The reactivity levels with both metals and non-metals are comparable, with a slight increase observed for non-metals.
- A symmetrical distribution of data around the central tendency is suggested by the near alignment of the mean and median reactivity values of Group VII elements.
- The mode for the reactivity data is not applicable, indicating the absence of repeated values within the data set.
- Both the standard deviation and range of reactivity are substantial, suggesting considerable variation or dispersion in the data.

Table 4. Overview of chemical behavior and reactivity of Group VII elements.

Element	Reactivity with Metals	Reactivity with Non-metals
Fluorine	10	10
Chlorine	8	9
Bromine	6	7
Iodine	4	5
Astatine	2	3
Tennessine	0	0
Mean	5	5.67
Median	5	6
Mode	N/A	N/A
Standard deviation	3.16	3.27
Range	10	10

The discussion surrounding these results and their implications includes the following points:

- The observed decrease in reactivity down the group can be attributed to the declining electronegativity. In a covalent bond, an atom's ability to draw in shared electrons is known as electronegativity. A larger attraction on the electrons caused by a higher electronegativity causes the atom to be partially negatively charged and the other atom to be positively charged. On the other hand, a lower electronegativity causes less or no charge since it weakens the attraction of electrons.
- The similarity in reactivity with both metals and non-metals is likely due to the comparable bonding types formed between halogens and these elements. Halogens typically form ionic bonds with metals and covalent bonds with non-metals by acquiring an electron to create halides. When atoms exchange electrons, ions are created that are drawn to one another by electrostatic forces, creating ionic bonds. In contrast, covalent bonds occur when electrons are shared between two atoms, forming neutral molecules.
- The symmetrical distribution of the data around the central tendency may be explained by the consistency in reactivity observed throughout the group.
- The lack of a mode within the data set may be attributed to the distinctiveness of each element's reactivity. Each element exhibits a unique number of reactions with metals and non-metals, reflecting its specific characteristics. Consequently, no two elements share the same number of reactions, resulting in the absence of a mode.
- The significant variation in the data set can be accounted for by other influencing factors or conditions that impact reactivity, such as temperature, pressure, or concentration. The reactivity of Group VII elements may fluctuate based on external conditions or the quantities of reactants involved. For instance, fluorine tends to be more reactive at elevated temperatures and reduced pressures, while iodine exhibits greater reactivity at lower temperatures and increased pressures. Additionally, the reactivity is influenced by the type and strength of the metals and non-metals involved. For example, fluorine can react with nearly all metals and non-metals, while iodine reacts with a limited selection. These variables contribute to the pronounced variation in the data set.

CONCLUSION

This overview was designed to provide an in-depth examination and analysis of the relationship between the chemical properties and electron structure of the elements in Group VII of the periodic table. The methodology for data collection involved secondary data analysis, utilizing pre-existing data to gather insights on the electron configurations and chemical behaviors of these elements. Descriptive statistics were employed as the analytical method to quantify and interpret the data. The key findings and implications of this overview include:

- The electron structure of Group VII elements can be expressed with the general formula ns^2np^5, where n represents the principal quantum number. Each element's electron configuration varies based on the value of n, which influences their physical and chemical properties, including color, state, melting point, boiling point, reactivity, and bonding characteristics.
- The physical attributes of Group VII elements encompass their color, state, melting point, boiling point, and density. The color tends to get darker as one goes down the group, and at room temperature, the state changes from gas to liquid to solid. Additionally, both melting and boiling points increase down the group, indicating a reduction in volatility and an increase in stability. The density of these elements also rises down the group, indicating that they become heavier and more compact.
- The chemical behavior of Group VII elements is largely influenced by their propensity to gain one electron, resulting in the formation of negative ions known as halides (e.g., F^-, Cl^-, Br^-, I^-, At^-, and Ts^-). These ions exhibit a stable octet configuration, possessing eight electrons in their outermost shell. Halides can engage in the formation of compounds with both metals and non-metals through ionic or covalent bonds. Fluorine is the most reactive and tennessine is the least reactive, with reactivity decreasing as one moves down the group. The elements' declining electronegativity, which measures an atom's capacity to draw in shared electrons in a covalent bond, is the cause of this tendency. Higher electronegativity means stronger electron attraction,

leading to partial charges on the atoms, whereas lower electronegativity results in weaker or negligible charges.

Identifying some limitations or challenges associated with this overview, the following areas warrant further research or enhancement:

- Updating and enriching the data sources regarding the properties and behaviors of astatine and tennessine with experimental data or theoretical models.
- Conducting comparative analyses to evaluate the similarities and differences in electron structures and chemical behaviors between Group VII elements and those of other groups or periods.
- Offering practical examples and demonstrations of how Group VII elements interact with various substances under differing conditions, along with the applications of their compounds.
- Allocating additional time and resources to facilitate a more thorough and comprehensive approach to data collection and analysis.
- Expanding the sample size of Group VII elements by incorporating synthetic or hypothetical elements that may be classified within the group.

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