

The Position and Classification of Hydrogen in the Periodic Table: A Comparative and Conceptual Analysis

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Abstract; Hydrogen occupies a unique and controversial position in the periodic table due to its simple atomic structure and diverse chemical behavior. Although it is traditionally placed at the top of Group 1, hydrogen displays properties that resemble not only alkali metals but also halogens, making its classification problematic. This ongoing debate highlights the limitations of rigid group-based classification within the periodic system. The purpose of this study is to examine the position of hydrogen in the periodic table by analyzing its atomic structure, chemical reactivity, and bonding behavior in comparison with different element groups. The research employs a comparative analytical method, focusing primarily on similarities and differences between hydrogen, alkali metals, and halogens, as well as considering alternative classification models proposed in modern chemistry. The findings indicate that hydrogen cannot be fully integrated into any single group due to its ability to exhibit both metallic and nonmetallic characteristics and to form compounds with varying oxidation states. The study concludes that hydrogen should be regarded as a unique element with a special or independent position in the periodic table, reflecting its exceptional chemical nature and theoretical significance.

Keywords: *Hydrogen, Periodic table, group similarities, halogens, chemical properties*

1. INTRODUCTION

Hydrogen is the most abundant element in the universe and plays a fundamental role in both chemical reactions and the structure of matter. Despite its simplicity and widespread occurrence, the classification of hydrogen within the periodic table remains one of the most debated issues in chemistry. Unlike most elements, hydrogen exhibits chemical properties that align with more than one group, which challenges traditional approaches to periodic classification.

The classification of elements is essential for understanding periodic trends, predicting chemical behavior, and developing coherent chemical theory. An accurate placement of hydrogen is therefore not only a matter of organization but also a theoretical concern that influences how chemical relationships are interpreted. Historically, hydrogen has been placed in Group 1 due to its single valence electron; however, its nonmetallic nature and ability to gain an electron suggest similarities with halogens as well.

Various scientific viewpoints have been proposed to resolve this issue, including placing hydrogen with alkali metals, aligning it with halogens, or assigning it a separate position. This study aims to address the following questions: Why is hydrogen difficult to classify within a single group? Which group similarities are most chemically significant? And is assigning hydrogen an independent position in the periodic table scientifically justified? By exploring these questions, the article seeks to clarify the unique chemical identity of hydrogen.

2. Atomic Structure and Fundamental Properties of Hydrogen

2.1 Atomic and Isotopic Structure

Hydrogen is the lightest element in the periodic table and has the simplest atomic structure. Its atom consists of a nucleus containing a single proton and one electron occupying the 1s orbital. The most abundant isotope of hydrogen is protium, which has no neutrons. In addition, hydrogen has two other naturally occurring isotopes: deuterium, containing one neutron, and tritium, containing two neutrons. These isotopes differ in mass but exhibit similar chemical behavior, although their physical properties vary. The simplicity of hydrogen's atomic structure plays a key role in its unique chemical characteristics and contributes to the difficulty of its classification within the periodic system.

2.2 Electronic Configuration and Bonding Behavior

The electronic configuration of hydrogen is $1s^1$, meaning it contains one valence electron. This configuration allows hydrogen to participate in chemical bonding by either losing, gaining, or sharing its electron. As a result, hydrogen is capable of forming both ionic and covalent bonds. In reactions with highly electropositive metals, hydrogen can form hydrides in which it exists as a negatively charged ion (H^-). In contrast, when bonded with nonmetals, hydrogen typically forms covalent compounds. This flexible bonding behavior distinguishes hydrogen from most other elements.

2.3 Oxidation States and Reactivity

Hydrogen commonly exhibits oxidation states of +1 and -1, depending on the nature of the elements with which it reacts. In acids and most covalent compounds, hydrogen exists in the +1 oxidation state. In metal hydrides, it appears in the -1 oxidation state. This ability to adopt different oxidation states enables hydrogen to act as both an oxidizing and a reducing agent. Such versatility in reactivity further complicates its placement within a single element group.

2.4 Physical Properties Relevant to Classification

Under standard conditions, hydrogen exists as a colorless, odorless, and tasteless diatomic gas (H_2). It has very low density and melting and boiling points compared to metallic elements. Unlike alkali metals, hydrogen does not exhibit typical metallic properties such as electrical conductivity or malleability. These physical characteristics support its classification as a nonmetal and highlight the limitations of placing hydrogen among metallic elements.

3. HYDROGEN AND GROUP 1 (ALKALI METALS): COMPARATIVE ANALYSIS

3.1 Similarities

Hydrogen shares several important characteristics with alkali metals, which explains its traditional placement above Group 1 in the periodic table. Both hydrogen and alkali metals possess a single valence electron, allowing them to form compounds in which they commonly exhibit a +1 oxidation state. Additionally, hydrogen is positioned directly above alkali metals in the periodic table, suggesting an electronic similarity based on valence structure.

3.2 Differences

Despite these similarities, significant differences exist between hydrogen and alkali metals. Hydrogen is a nonmetal and exists as a diatomic gas under normal conditions, whereas alkali metals are soft, highly

reactive solids. Alkali metals display strong metallic character and readily form positively charged ions (M^+), while hydrogen can exist as either a positive or negative ion depending on the reaction. Furthermore, alkali metals predominantly form ionic compounds, whereas hydrogen frequently forms covalent bonds.

3.3 Evaluation

Although hydrogen shares certain electronic features with alkali metals, these similarities are insufficient to justify its full inclusion in Group 1. The absence of metallic properties, its gaseous physical state, and its ability to form both positive and negative ions distinguish hydrogen from true alkali metals. Therefore, while hydrogen's placement above Group 1 has some theoretical basis, it does not fully reflect the element's complex chemical behavior, making this classification incomplete.

4. HYDROGEN AND GROUP 17 (HALOGENS): COMPARATIVE ANALYSIS

4.1 Similarities

Hydrogen shares several notable features with the halogens (Group 17), which is why some chemists have argued that hydrogen could be placed above fluorine rather than above lithium. First, hydrogen is able to gain one electron under certain conditions and form the hydride ion (H^-), corresponding to the -1 oxidation state—an important characteristic of halogens. Second, hydrogen exists in nature as a diatomic molecule (H_2), similar to halogens such as F_2 and Cl_2 , which also exist as diatomic molecules in their elemental form. Third, hydrogen demonstrates nonmetallic behavior in many respects, including relatively low density, nonmetallic physical properties, and a strong tendency to form covalent bonds with many nonmetals.

4.2 Differences

Despite these similarities, hydrogen differs from halogens in several fundamental aspects. A key difference is electron affinity: halogens have very high electron affinity and strongly attract electrons, which contributes to their high reactivity. Hydrogen's electron affinity is significantly lower, meaning it does not gain electrons as readily as halogens. Reactivity is another major distinction. Halogens are among the most reactive nonmetals and often react vigorously to form salts with metals, whereas hydrogen's reactivity depends strongly on conditions such as temperature, catalysts, or the presence of specific reactive partners. In addition, the compound types formed by hydrogen are far more diverse than those formed by halogens. While halogens commonly form halides and strong oxidizing compounds, hydrogen forms acids, hydrides, covalent molecular compounds (e.g., water, ammonia, methane), and complex bonding environments such as hydrogen bonding.

4.3 Evaluation

The comparison shows that hydrogen does share some structural and electronic features with halogens, especially its ability to form a -1 oxidation state and its diatomic form. However, the differences in electron affinity, typical reactivity patterns, and the wide variety of compound types formed by hydrogen limit the accuracy of a Group 17 classification. Therefore, placing hydrogen among the halogens may highlight one aspect of its behavior, but it does not fully represent hydrogen's overall chemical identity.

5. ALTERNATIVE CLASSIFICATION PERSPECTIVES

5.1 Hydrogen as a Standalone Element

A widely supported modern approach is to treat hydrogen as a standalone element with a special position in the periodic table. This perspective is based on the fact that hydrogen does not consistently behave like any single group. Its unique combination of electronic simplicity, variable oxidation states, and flexible bonding behavior makes it an exception to typical periodic patterns. As a result, some periodic table designs place hydrogen separately at the top of the table or in a floating position to reflect its exceptional chemical nature.

5.2 Periodic Table Symmetry and Conceptual Models

Some researchers discuss hydrogen's placement using broader conceptual models of periodicity, symmetry, and periodic table design. In such approaches, the periodic table is viewed not only as a list of elements but also as a structured model that reflects repeating chemical relationships. Hydrogen becomes challenging in these models because it disrupts symmetry: its electron configuration suggests one classification, while its chemical behavior suggests multiple. Consequently, alternative periodic table designs—including extended, left-step, or symmetry-based tables—often attempt to give hydrogen a position that improves theoretical consistency, even if it differs from traditional layouts.

5.3 Educational vs. Theoretical Representations

Another important modern viewpoint distinguishes between educational convenience and theoretical accuracy. In many school-level periodic tables, hydrogen is placed above Group 1 because it is simple to explain through valence electron logic (one electron, similar to alkali metals). However, from a theoretical and research perspective, this placement is often considered incomplete because it does not reflect hydrogen's nonmetallic properties and its halogen-like behavior in some reactions. Therefore, educators may prioritize simplicity, while scientists may prioritize a classification that better represents hydrogen's full chemical versatility.

5.4 Summary of Modern Scientific Viewpoints

Modern chemical literature generally recognizes that hydrogen cannot be fully explained by assigning it to either Group 1 or Group 17 alone. While its electronic structure supports similarities with alkali metals, and certain oxidation behaviors resemble halogens, neither grouping accounts for hydrogen's full range of reactivity and bonding. For this reason, many contemporary discussions support presenting hydrogen as a unique element with a special placement in the periodic table. This approach better reflects hydrogen's dual character and preserves the explanatory power of periodic classification without forcing the element into an unsuitable category.

6. THE CLASSIFICATION PROBLEM OF HYDROGEN

Hydrogen is difficult to classify because no single periodic group captures its full chemical behavior. The standard table places hydrogen above Group 1 largely because it has one valence electron ($1s^1$) and often forms compounds where hydrogen is effectively +1. However, hydrogen is not a metal under ordinary conditions and does not show the typical metallic bonding, conductivity, and solid-state properties that characterize alkali metals. At the same time, hydrogen can also occur as H^- (hydride) in ionic metal hydrides, a feature that resembles halogens' tendency to form -1 ions, yet hydrogen's electron-gain tendency and overall reaction patterns do not match the consistently high electron affinity and strong oxidizing behavior typical of Group 17.

From a conceptual standpoint, hydrogen is often treated as a “borderline” element—one whose behavior overlaps multiple families without fully belonging to any of them. Modern discussions emphasize that hydrogen’s dual character (metal-like in some contexts, nonmetal-like in many others) makes it an exception to simplified periodic trends and labels (metal vs. nonmetal; typical oxidation patterns; uniform group chemistry). This is why several classification proposals exist simultaneously, including placement in Group 1, Group 17, dual positioning, or a stand-alone placement designed to reflect its exceptional status.

7. IMPLICATIONS FOR CHEMICAL THEORY AND EDUCATION

Hydrogen’s disputed position shows that the periodic table is not only a chart of atomic numbers but also a theoretical model that tries to summarize chemical relationships. Hydrogen challenges rigid classification because it demonstrates how electron configuration alone cannot always determine “group identity,” especially when bonding diversity and oxidation-state variability are considered. In broader theoretical debates (for example, discussions about metallic/nonmetallic boundaries and periodic trends), hydrogen is frequently used as an example of why chemical categories can be context-dependent rather than absolute.

For chemistry education, this has a practical message: instructors may present hydrogen in Group 1 for introductory simplicity, but students should also learn that professional chemistry recognizes hydrogen as unique and often represented in alternative ways (e.g., shown at the top of both Groups 1 and 17, or placed separately). Using hydrogen as a “case study” can improve learners’ understanding that the periodic table balances pedagogical clarity with scientific nuance, and that multiple representations may be valid depending on the learning goal (trend prediction vs. conceptual accuracy).

8. CONCLUSION

This article addressed a central question in periodic classification: Where does hydrogen most appropriately belong in the periodic table? Comparative analysis shows that hydrogen shares important features with Group 1 (one valence electron; frequent +1 oxidation state) while also displaying meaningful parallels with Group 17 (formation of -1 hydride; diatomic elemental form; nonmetallic character). Nevertheless, major differences in physical nature, electron-gain tendencies, and compound diversity prevent hydrogen from fitting fully into either family.

The evidence supports the view that hydrogen should be treated as a chemically unique element, and that an independent or special placement best communicates its exceptional behavior without forcing it into an imperfect group category. Such a conclusion does not weaken the periodic table; rather, it strengthens it by acknowledging that periodic classification is a powerful model—yet one that must sometimes accommodate exceptional cases like hydrogen.

REFERENCES

- Petruševski, V. M., & Cvetković, J. (2018). On the ‘true position’ of hydrogen in the periodic table. *Foundations of Chemistry*, 20(3), 251-260.
- Petruševski, V. M., & Cvetković, J. (2017). ON THE ‘TRUE POSITION’ OF HYDROGEN IN THE PERIODIC TABLE. *Contributions. Section of Natural, Mathematical & Biotechnical Sciences*, 38(1).
- Labarca, M. G., & Srivaths, A. (2016). On the placement of hydrogen and helium in the periodic system: a new approach.

- Dash, H. H. (1964). Position of hydrogen in the periodic system of elements. *Nature*, 202(4936), 1001-1003.
- Jensen, W. B. (1986). Classification, symmetry and the periodic table. In *Symmetry* (pp. 487-510). Pergamon.
- Hensel, F., Slocombe, D. R., & Edwards, P. P. (2015). On the occurrence of metallic character in the periodic table of the chemical elements. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 373(2037).
- Cao, C., Vernon, R. E., Schwarz, W. E., & Li, J. (2021). Understanding periodic and non-periodic chemistry in periodic tables. *Frontiers in Chemistry*, 8, 813.

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