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Triads Involving Hydrogen, Helium and Yttrium

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ABSTRACT

The triads H-F-Cl and He-Ne-Ar have been discussed and these triads are found useful in connecting H and He with respective halogen and noble group elements. Triad of yttrium with lutetium and lawrencium shows kinship of the later two with yttrium in comparison to La and Ac and favors their placement in group-III B of the periodic table. The Dobereiners' triads, a group of three elements with almost similar appearance and properties, is the first significant attempt to group elements by developing relation between the properties of the elements and their atomic weights [1]. Mendeleev [2] used the triad behavior as the basis for predicting the properties of three "missing elements". Later on the electronic configuration of the elements revealed that the triads belong to the same group of modern periodic table [3] and so they exhibit similarities in their properties. All the triads, twenty six in number, so far recognized have the elements of the same periodic group of the table [4].The new triads including H and He have been identified and their usefulness along with Y triad [4] as teaching aid in periodic system is the content of the present investigation.

Keywords: Triads, hydrogen, helium, yttrium.

Group Position of H and He

Hydrogen ($1s^1$) and helium ($2s^2$) are the member of alkali and alkaline earth metals [5-8] respectively. The position of hydrogen with the alkali metals is based on the similarity of the valence shells of this family: each of the elements possesses a half-filled s-orbital, namely, H $1s^1$, Li $2s^1$, Na $3s^1$, and so on. Like M^+ ion of alkali metals (1A), H has also well established H^+ ion chemistry, acid-base chemistry, in particular. However, the properties of hydrogen differ significantly from those of the alkali metals. Hydrogen is a diatomic gas like halogens, not a reactive metal. In addition to this it forms hydride ion, H^- by gain of an electron as halide ion, X^- is formed by halogens. The ion, H^- reacts with alkali metals and form salt like hydrides comparable to the salts formed by the reaction of the halogens with alkali metals. The compounds of hydrogen with nonmetals usually are covalent in nature. On the other hand, alkali metal gives ionic compounds with nonmetals. These resemblances of hydrogen with halogens favor the inclusion of hydrogen with halogens (VIIA).Though hydrogen is usually placed at the head of group IA but there are the periodic tables that also place it at the head of VIIA group, giving more than one position to hydrogen in the periodic system [9, 10]. Not only this, some periodic modifications give a separate position to hydrogen as on the top middle of the periodic table [11-13]. The electronic structure of helium is similar to that of alkaline earth metals [14] i.e. it has completely filled s- orbital so G.T. Seaborg in the year 1969 placed it next to H instead of on top of Ne in extended form of the periodic table [8]. Helium, except its electronic structure, has little in common with IIA members. However, like noble gases, it is an extremely inert monoatomic gas and largely exhibits the behavior of noble gases. So the position of helium has ultimately been accepted in periodic classification with zero group elements.

The members of IIIB Group

The complete or incomplete electronic shells were used by Bohr [14] to classify the elements and La and Lu both contain two imperfect shells so they were grouped as transition elements and La is placed as the congener of Sc and Y. Goldschmidt [15] used "lanthanide" to mean those elements with atomic number greater than 57 but like lanthanum. There are many periodic modifications [8, 16-18] which are based on natural order of atomic number, place Lu and Lr rather than La and Ac in group –IIIB below Y. W.B. Jensen [19] discussed the properties of Lu and Lr and presented great evidences to support unanimously the placement of Lu and Lr rather than La and Ac, in group- IIIB. In the same article, the later two elements have been added to the list of elements of irregular electronic configuration and placed with inner transition elements. Recently M. Laing [20] proposed a revised periodic chart with repositioning of lanthanide and actinides and all the four elements- La, Ac, Lu and Lr are included in group-IIIB. However, the International Union of Pure and Applied Chemistry (IUPAC) [21] table separates out 15 lanthanides, La-Lr and 15 actinides Ac-Lr by leaving gaps in group 3 under Sc and Y.

The Triads

The groupings of the elements (figure 1) H-F-Cl, He-Ne-Ar and Y-Lu-Lr [4] obey the law of triad i.e. the atomic weight of middle element in each triad is close to the average of the atomic weights of the other two elements (table-1). A numerical relationship in their size also makes them good triads (table-2).

Table 1 Triads of H, He and Y.

Triad	Accepted Atomic Weight			Est. At. Wt. of 2nd element.
1	1.00 (H)	18.99 (F)	35.45 (Cl)	18.26 (F)
2	4.00 (He)	20.18 (Ne)	39.94 (Ar)	21.97 (Ne)
3	88.90 (Y)	174.97(Lu)	262.00 (Lr)	175.40 (Lu)

Table 2 Atomic size (A^O) relation in triads of H, He and Y

Triad	Accepted covalent radii(A^0)			Estimated covalent radii (A^0)	Difference in covalent radii (A^0) of 2nd element
1	0.30 (H)	0.64 (F)	0.99 (Cl)	0.64 (F)	0.00
2	0.93(He)	1.12 (Ne)	1.54 (Ar)	1.24 (Ne)	0.12
3	1.06 (Y)	0.85(Lu)	0.95(Lr)	1.00 (Lu)	0.15*

* Ionic radii of M^{+3}

The question of resemblance of H and He with VIIA and zero groups respectively, has often been raised by students during teaching of periodic classification of the elements. A simple but definite answer to the question is the triad behavior of these elements. H does not form triad with Li and Na but it does so with F and Cl. Similarly no triad is formed by He with Be and Mg. However, He -Ne -Ar is such an effective triad that makes He the known member of zero group. Thus in H electronic structure as well as its triad behavior both is equally important whereas in He it is its triad nature that dominates and it shows almost no resemblance with alkaline earth metals.

To chemistry educators, the subject concerned with the family member of III-B group, always puts them in a difficult position with their students, as no definite solution exists in chemical literature to the question of d^1-family. Ibrahim [4] has recently reported ten d-block triads including the triad, Y-Lu-Lr. All these triads involve elements of 4d, 5d and 6d series only. The 3d elements have no such numerical relationship with 4d and 5d elements. However, La and Ac do not form triad with Y when grouped as elements of III-B group. This deviation reveals that La and Ac, though they have many similarities in properties with Sc and Y, are not the true members of III-B group, as they do not follow the group trends of d-block elements.
The atomic radii (A^0) of IIA and some d-block elements [22] are presented in table-3. Atomic size, a physical property of the elements that exhibits a definite group trend, increases on going down the group. However, due to post lanthanide contraction effect [23] a decrease or little change in size is observed between the elements of 4d and 5d. The III-B group with Lu, as member follows the usual group trend in size of the elements that are observed in d-block (table-3). On the other hand, if La is considered as member of the III-B group it shows group trends as that of s-block elements. This atomic size relationship of Lu further substantiates the triad behavior in justifying the position of Lu and Lr as elements of III-B group. Thus the triad behavior of Y is useful in making the simple and meaningful solution to the subject of its higher congeners in III-B group. Furthermore, it is interesting to mention here is that a new triad, Sc-Y-La is formed when La is considered as an element of 5d family. This new intra block triad, Sc (3d)-Y (4d)-La (4f) connects elements of d-block in terms of triad behavior with f-block elements and suggests that a new series of triads also exist in the periodic table.

CONCLUSIONS

The Dobereiners' triads, an early attempt to group elements with numerical relationship, are also useful in assigning the particular position of the elements like hydrogen, helium, lutetium, and lawrencium which have more than one position in the frequently used medium long form of the periodic table. In periodic teaching, the triad numerical relationship that have been discussed in the present study will help to the chemistry educators to evolve a new approach with respect to the position of the elements, H, He, Lu, and Lr in the periodic classification of the elements.

Table 3 Atomic radii (A^0) of IIA and some d-block elements.

IIA	IIIB	IIIB	IVB	VB	VIB	VIIB
Ca 1.97	Sc 1.61	Sc 1.61	Ti 1.45	V 1.32	Cr 1.25	Mn 1.24
Sr 2.14	Y 1.81	Y 1.81	Zr 1.60	Nb 1.43	Mo 1.36	Tc 1.36
Ba 2.17	La 1.88	Lu 1.73	Hf 1.57	Ta 1.43	W 1.37	Re 1.37

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