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A Specific Periodic Table for Chemistry of Organic, Semi-Organic and Inorganic Elements: Compatibility with the Even-Odd Rule, the Number of Electrons and the Isoelectronicity Rule

Geoffroy Auvert

Grenoble Alpes University, Grenoble, France
Email: geoffroy.auvert@grenoble-inp.org

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Abstract

Following the introduction of the new even-odd and isoelectronic rules and definitions affecting the understanding of electronic structure and bonds, the author has thought necessary to summarize understandings in the form of a table. The classical periodic table, a simple tool used by generations of physicists, is here extended to become a useful tool aimed specifically at chemists. In chemistry, position and number of covalent bonds of each atom are needed, as well as the exact location of charges. The table gives the number of possible bonds for each element and reveals how it is affected by charges. Additionally, the specific table indicates for each atom its isoelectronic elements and highlights the distinction between organic and inorganic elements. Discussion is led on the first two rows of the table by successfully comparing its statement with more than 50 well-known liquid and gaseous compounds.

Keywords

Chemistry, Periodic Table, Organic, Inorganic, Semi-Organic, Even-Odd, Rule, Inner Shell

1. Introduction

When Mendeleyev elaborated his periodic table in the 1860's [1], he classified elements by their atomic weight and by columns containing elements with the same physical or valence properties [2]. The first parameter, the atomic weight, has been changed by Van den Broek who proposed to classify elements by their number of positive charges in the nucleus [3]. This periodic table classifies isotopes having the same positive charge, at the same place. This periodic table is today a reference even in chemistry [4]. Many variations of the periodic table exist, each trying to complete it for a specific purpose, but none gives indications of chemical bonds or of the location of electronic charges. Understanding bonds and charges positions could be very useful in chemistry, mainly when studying compounds structures or predicting chemical reactions.

The present article is an attempt at addressing this limitation with a *specific periodic table for chemistry*. In this table, elements are classified by their number of electrons and their electronic structure in compounds, including when bearing charges. This specific table is based on the even-odd and the isoelectronicity rules recently proposed [5] [6] [7] [8] [9]. The even-odd rule gives the number of covalent bonds an element can have and the isoelectronicity rule allows to know where and how to add a charge when an element of a compound is needed. The *specific periodic table for chemistry* presents elements very similarly to the classical periodic table, with elements in rows and columns, but it additionally includes electronic structures of atoms when bearing charges.

First, we briefly recall the rules used and presents the two first rows of the *specific periodic table for chemistry*. It describes features common to atoms within each cell as well as to neighboring cells. The difference between *organic*, *semi-organic* and *inorganic* elements is then detailed, linked to the number of electrons pairs in their shells. We end with a list of neutral and charged compounds compatible with the featured table. This list is composed of compounds with elements of the main group [10] [11].

Compounds used to illustrate the use of the table are known to exist under standard conditions in liquid or gaseous phase [12], *i.e.* far from extreme pressure and temperature. This evidently removes solid structures from our study [13] [14].

To remain conform to the notation used in previous papers dealing with the even-odd rule, compounds are noted in capitals: NH3 is for neutral ammonia, NH4(+) is an ammonia cation and NH2(−) an ammonia anion [4] [5] [6] [7] [8] [9].

2. Even-Odd and Isoelectronicity Rules

As highlighted in previous articles, charged elements that follow the even-odd rule can only bear a single charge. Another criterion of the rule is that a connection between two elements of a compound can only be a single covalent bond [5] [6] [7] [8] [9].

The even-odd rule offers a method to calculate the number of covalent bonds an element can have when part of a compound [7]. The maximum number of covalent bonds is obviously linked to the valence number since valence electrons are available for bonding. However, valence electrons are not always involved in bonds and those unbound remain in pairs. The number of bonds of an element in a compound may hence be smaller than expected.

The isoelectronicity rule allows an element in a compound to be replaced by an element of the nearest column in the classical periodic table [8]. This is possible first: when both elements have the same external electronic structure and second when multi-charged elements are excluded.

3. Specific Periodic Table for Chemistry of Main Group Elements

Table 1 lists the first two rows of a *specific periodic table for chemistry* with 8 elements of the main group [10] [11], including specifics on *organic*, *inorganic* and *semi-organic* elements [15].

In Table 1, charged and uncharged elements are placed in columns numbered from 0 to 8.

Table 1. The first two rows of the *specific periodic table for chemistry* with elements from the main group. The classification of neutral elements, in rows and in columns is identical to the classical periodic table.

	Column	**Number**							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	H(+) 0 bond **0,0**	H 1 bond **0,1**	H(−) 2-0 bonds **0,2**						
2	Li(+) 0 bond **2,0**	Li Be(+) 1 bond **2,1**	Li(−) Be B(+) 2-0 bonds **2,2**	Be(−) B C(+) 3-1 bonds **2,3**	B(−) C N(+) 4-2-0 bonds **2,4**	O(+) N C(−) 3-1 bonds **4,3**	F(+) O N(−) 2-0 bonds **6,2**	F O(−) 1 bond **8,1**	F(−) 0 bond **10,0**

The method used to build and to read this *specific periodic table* is detailed in the remaining of the present article.

4. Classifying Charged and Uncharged Elements

4.1. Common Electronic Structures

In Table 1, like in the classical periodic table [1], elements in their neutral state are identified by their acronym and listed in rows and columns by their physical or chemical properties.

Table 1 additionally lists negative or positive states of 8 elements. In a charged state, a column shift highlights that the chemistry is different from that of the neutral state. To be more precise, an element that has lost an electron will adopt the electronic structure of the element to its left. Inversely, an element that has gained an electron will have a similar structure than the element to its right.

Hence in columns 2 to 6 of row 2, each cell of Table 1 contains three distinctive elements in differing charge states: one neutral element and two charged elements. Note that elements within the same cell have common properties.

Illustration: Neutral boron B has the same electronic configuration than C(+) and Be(−), that leads to similar fluorine structures, CF3(+), BF3 and BeF3(−).

4.2. Border Cases

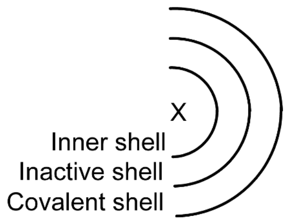
On the borders of Table 1, cells of columns 1 and 7 contain only two elements. Cell 7 for instance contains F and O(−). Both can form a compound with an hydrogen atom: HF and OH(−). Both have the same electronic structure with a mono-bonded hydrogen.

Column 0 contains only one element, which cannot build bonds. Li(+) has an electronic configuration that makes it resemble inert gases.

5. Electronic Structure

5.1. Three Electrons Shells around the Nucleus

According to the even-odd rule [8], electrons of an atom in a compound dispatch into three electrons shells [15]. They can be schematically represented around the nucleus as follow:



X represents the nucleus.

The most inner shell is naturally named the *inner shell*. The second is the *inactive shell*. The outer shell is the *covalent shell* in which one electron is placed for each covalent bond of the element.

5.2. Numbers of Covalent Bonds Erected by Elements in a Compound

In the *specific periodic table,* two series of numbers can be found at the bottom of each cell. The top series indicate how many covalent bonds the elements can erect; depending on the compound they find themselves in.

Illustration: When in a compound, neutral boron (column 3 with series 3-1) may for instance erect 3 or 1 covalent bond(s). Examples of compounds containing boron include BF3 and BF [12]. Note that literature is not unanimous on the number of bonds boron has in the latter compound; it varies from three [16] to one [7]. This last reference written by the author, affirms that two chemical elements cannot be linked through multiple bonds.

5.3. The Number of Electrons in the Outer Shells

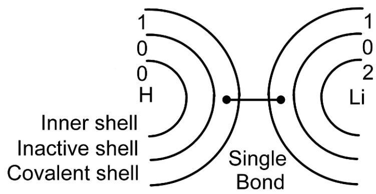
The bottom series gives first the number of electrons in the inner shell. The number of electrons in this shell is always even [7]. The second number indicates the total numbers of electrons in the outer shells.

Illustration: In row 2 of column 4 for instance, the bottom series for neutral carbon is **2,4**. There are 2 electrons in the inner shell and 4 electrons that can either be found in the inactive shell, in the covalent shell or in both. Neutral carbon can set up 4, 2 or 0 covalent bonds (top series), which means that there are respectively 0, 2 or 4 electrons in the inactive shell. Three compounds exemplify these various configurations: CH4 (four bonds), C2H2 (each carbon has two bonds) and carbon mono-element C without bond [15].

5.4. Electrons in the Shells of an Element in a Compound

Building on, the numbers in the series can be used to deduce the numbers of both series of a cell.

Illustration: The LiH compound can be produced between 700˚C and 900˚C and electronic structures of both atoms are as illustrated:



In this example, hydrogen with one electron forms a covalent bond represented by a line with an electron of lithium, both in the covalent shells of their respective atom. The inner and inactive shells of hydrogen are empty. Second series is therefore **0,1**. In lithium, the three shells contain 2, 0 and 1 electron respectively. The second series is therefore **2,1**.

Another example could be carbon in CH4. It has two electrons in the inner shell and four electrons in the covalent shell. Each carbon electrons erects one single bond with each single hydrogen electron [5] [15]. The second series is **2,4**.

5.5. Total Number of Electrons

The total number of electrons can be found by adding both numbers of the bottom series in the cell. It means that elements located in the same cell have the same overall number of electrons. In the *specific periodic table for chemistry*, the total number of electrons ranges from 0—positively charged hydrogen, *i.e.* a proton—up to 10—column 8 of row 2—by steps of one electron from left to right.

For each element, the total number of electrons is naturally charge sensitive. As mentioned in **Chapter** 4, a positive charge is placed on the left side of neutral element and a negative charge is placed on the right.

This total number of electrons also equals the atomic number used for each element in the classical periodic table.

In **Table 1**, this classification using the electrons number is fully compatible with the definition of the isoelectronicity rule used in this paper and defined in [7].

Illustration: O(+), N and C(−) in column 5, are in the same column and are isoelectronic.

6. Organic, Semi-Organic and Inorganic Elements

One would have rapidly noticed that the *specific periodic table for chemistry* contains green and white cells as in [15]. In white cells, the number of electrons in the inner shell is constant along the row as in the classical periodic table: 0 in row 1 and 2 in row 2. On the contrary, in green cells, the number of electrons in the inner shell is always higher than that found in the classical periodic table. It increases by steps of 2 electrons from left to right.

Another difference between green and white cells lies in the number of electrons in the outer shells of the elements. It increases by one from left to right in white cells and decreases by one from left to right in green cells.

6.1. Three Consecutive Cells

In **Table 1**, cells are based on two colors: white or green. A white background indicates elements in an *inorganic* state. When an element is inorganic in its three states—negatively or positively charged, or neutral—it will be named *inorganic*. A green background indicates an *organic* state. An element, neutral or charged, occupying three consecutive green cells is defined as *organic*. Element that appears in three consecutive cells with two different colors are named *semi-organic*. Two elements in **Table 1** are *semi-organic*, C and N [15].

Illustration: B(+), neutral B and B(−) are in columns 2, 3 and 4 with white backgrounds which makes B an *inorganic* element. On the contrary, O(+), neutral O and O(−) are respectively in column 5, 6 and 7 with green background which makes O an *organic* element.

In column 5, neutral nitrogen is placed in a green cell and can have up to 3 bonds instead of 5 from the classical table. Since N(+) appears in a white cell, it is a *semi-organic* element. Unlike carbon, the maximal number of bonds is decreasing from left to right. N(+), neutral N and N(−) can erect 4, 3 and 2 bonds respectively. The corresponding compounds are NH4(+), NH3 and NH2(−). Only N(+), in a white cell, possesses the same number of electrons in the inner shell than indicated in the periodic table.

6.2. Number of Electrons in the Inner Shell and the Difference between Organic, Semi-Organic and Inorganic Elements

In each cell of **Table 1**, the first number of the second series indicates the number of electrons in the inner shell.

Illustration for white cells: the number of electrons in the inner shell is constant in each row as in the classical periodic table: 0 in row 1 and 2 in row 2. In the second raw of **Table 1**, Li, Be and B are *inorganic* with 2 electrons in the inner shell as in the periodic table. In column 4, B(−), neutral C and N(+) appear in a white cell with 2 electrons in the inner shell.

Illustration for green cells: O and F have a higher number of electrons in the inner shell as other elements of the same row: 6 and 8 respectively. In column 5 with green color, O(+), N and C(−) have 4 electrons in their inner shell. The lower number of electrons in the outer shells of these elements is explained by a transfer of electrons pairs into their inner shells.

Note that for organic elements, the number of electrons in the inner shell always increases by step of one pair from left to right.

7. Isoelectronicity Rule for *Organic, Semi-Organic* and *Inorganic* Elements

The isoelectronicity rule states that an element in a compound can be substituted by another when they both have 1) the same number of electrons in the inactive shell, 2) the same number of electrons in the covalent shell and 3) the same number of possible bonds [8].

Elements sharing a single cell are isoelectronic and consequently have the same chemistry.

Illustration: In Table 1, Li(−), Be and B(+) can have the same structure with two bonds ended by OH, Li(OH)2(−), Be(OH)2 and B(OH)2(+). These three elements are isoelectronic in these compounds with two covalent bonds and an empty inactive shell.

In column 6 of row 2, neutral N and O(+) are isoelectronic and can be found in similar structures NH3 and H3O(+).

8. Applications of the "Specific Periodic Table for Chemistry"

To illustrate the proposed *specific periodic table for chemistry*, several small molecules with elements of Table 1 are shown in Table 2. Compounds listed in Table 2 are known in liquid or gas phases.

Table 2. Compounds compatible with the *specific periodic table for chemistry*. Every compound is classified according to 1) the column number in row 1 and 2 of Table 1, 2) with every allowed covalent number of bonds and 3) to the charge of the element.

State names	Ions or molecules	Type	Bonds	Reference
Column 0	H(+)	ionic	no bond	dissociation of H2
Inorganic	Li(+)	ionic	no bond	dissociation of Li2
Column 1	H2 HF	neutral	one bond	[16]
Inorganic	Li2 LiH LiOH	neutral	one bond	[16]
	LiBr LiCl LiI LiF	neutral	one bond	Halogen [16]
	Be(+) in BeF(+)	ionic	one bond	ionization in liquid BeF2
	Be(+)O(−) is BeO	ionic	one bond	Liquid Gas [16]
	Be(+)OC(−)O2 is BeCO3	ionic	one bond	Liquid Gas [16]
Column 2	H(−)	ionic	no bond	dissociation of H2 [16]
Inorganic	Li(−)	ionic	no bond	dissociation of Li2 [16]
	Be	neutral	no bond	monoatomic beryllium [15]

Continued

	B(+)	ionic	no bond	dissociation of B2
	H(−) in HF2(−)	ionic	2 bonds	liquid HF [16]
	Li(−) in LiO2(−)	ionic	2 bonds	[16]
	BeH2 Be(OH)2	neutral	2 bonds	[16]
	BeI2 BeF2 BeCl2	neutral	2 bonds	[16]
	B(+) in BCl2(+) BF2(+)	ionic	2 bonds	dissociation B2X4 [16]
Column 3 Inorganic	Be(−)H	ionic	one bond	dissociation from BeH2
	BAs BF BN	neutral	one bond	ionization in liquid BeF2
	B2	neutral	one bond	Liquid Gas [16]
	C(+)O(−) is CO	ionic	one bond	Gas [16]
	Be(−)F3	ionic	3 bonds	Liquid Gas [16]
	B(OH)3 B(NO3)	neutral	3 bonds	Sol Liq Gas [16]
	BBr3 BCl3 BF3	neutral	3 bonds	Halogen Liq Gas [16]
	C(+)H3 is CH3(+)	ionic	3 bonds	dissociation of C2H6 [16]
Column 4 Inorganic	B(−)	ionic	no bond	Dissociation of B2 [16]
	BCl2(−) BF2(−)	ionic	2 bonds	Halogen dissociation B2X4 [16]
	B(−)F4 of BF4(−)	ionic	4 bonds	Halogen [16]
	C	neutral	no bond	Monoatomic C [16]
	CH2	neutral	2 bonds	dissociation C2H4 [16]
	CH4	neutral	4 bonds	(well known) [16]
	N(+)	ionic	no bond	dissociation of N2 [16]
	N(+)H2	ionic	2 bonds	dissociation of N2H4
	N(+)H4 is NH4(+)	ionic	4 bonds	(well known) [16]
Column 5 Organic	ClO(+)	Ionic	one bond	dissociation of Cl2O [16]
	H3O(+)	ionic	3 bonds	(well known) [16]
	NH	neutral	one bond	Dissociation of N2H2 [16]
	NH3	neutral	3 bonds	(well known) [16]
	CH(−)	ionic	one bond	Acetylene dissociation [16]
	CH3(−)	ionic	3 bonds	C2H6 dissociation [16]
Column 6 Organic	F(+)	ionic	no bond	F2 dissociation
	H2F(+)	ionic	2 bonds	Liquid HF [16]
	O	neutral	no bond	mono-atomic oxygen [12]
	H2O	neutral	2 bonds	(Well known) [16]
	N(−)	ionic	no bond	N2 dissociation
	NH2(−)	ionic	2 bonds	dissociation of N2H4 [16]
Column 7 Organic	HF	neutral	one bond	Liquid Gas [16]
	OH(−)	ionic	one bond	(well known) [16]
Column 8 Organic	F(−)	ionic	no bond	F2 dissociation

Table 2 is a significant support for the proposed "specific periodic table for chemistry" by including charges and equivalent covalent bonding.

9. Conclusions

An alternative way to order elements is needed to address specifically the needs of chemists. Inspired by the well-known classical periodic table, the *specific periodic table for chemistry* presented here lists charged and uncharged elements when part of compounds in liquid or gaseous phases. Elements are ordered by increasing total number of electrons, although the table carefully details the number of electrons in each shell around the nucleus. Application of this periodic table to numerous known charged and uncharged compounds forms a strong experimental support to its theoretical formulation.

The table illustrates the fundamental difference between organic and inorganic elements, making it possible at last to reconciliate various definitions of organic matter. Unsurprisingly, inorganic elements see the number of electrons in the inner shell constant whatever their charge state. On the contrary, organic or semi-organic elements see electrons migrate between their inner and outer shells. This remarkable property of organic elements makes them build fewer bonds when gaining additional electrons.

By indicating the maximum number of bonds of elements and linking it to the local charge, the *specific periodic table for chemistry* can become a useful tool for chemists studying compounds structures. This table can be used to predict chemical reactions or how to form isoelectronic compounds by using elements in the same cell.

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