# A FIRST LOOK AT THE PERIODIC TABLE

At the end of the 18th century, Lavoisier compiled a list of the 23 elements known at that time; by 1870, 65 were known; by 1925, 88; today, there are 116 and still counting! These elements combine to form millions of compounds, so we clearly need some way to organize what we know about their behavior. By the mid-19$^{th}$ century, enormous amounts of information concerning reactions, properties, and atomic masses of the elements led researchers to note recurring, or *periodic,* patterns of element behavior. In 1871, the Russian chemist Dmitri Mendeleev organized this information into a table that listed the elements by increasing atomic mass, arranged so that elements with similar chemical properties fell in the same column. The modern **periodic table of the elements,** based on Mendeleev's earlier version—but arranged by atomic number, not mass—is one of the great classifying schemes in science and has become an indispensable tool to chemists.

# The Periodic Table

## Organization of the Periodic Table

**A modern version of the periodic table is formatted as follows:**

1. **Each element has a box that contains its atomic number, atomic symbol, and atomic mass. The boxes lie in order of *increasing atomic number* (number of protons) as you move from left to right.**
2. **The boxes are arranged into a grid of periods (horizontal rows) and groups (vertical columns). Each period has a number from 1 to 7. Each group has a number from 1 to 8 *and* either the letter A or B. A new system, with group numbers from 1 to 18 but no letters, appears in parentheses under the number letter designations. (Most chemists still use the number-letter system, so the text retains it and shows the new numbering system in parentheses.)**
3. **The eight A groups (two on the left and six on the right) contain the *main group*, or *representative, elements.* The ten B groups, located between Groups 2A(2) and 3A(13), contain the *transition elements.* Two horizontal series of *inner transition elements,* the**

**lanthanides and the actinides, fit *between* the elements in Group 3B(3) and Group 4B(4) and are usually placed below the main body of the table.**

**النظرة الاولية للجدول الدوري**

**في نهاية القرن الثامن عشر العالم لافوازيه اكمل قائمة بـ23 عنصر في وقتها ثم في عام 1870 اصبحت 65 عنصر وفي عام 1925 اصبحت 88 عنصر اما الان فهي 116عنصر والعدد مستمر بالزيادة وهذه العناصر تتحد لتكون ملايين المركبات.**

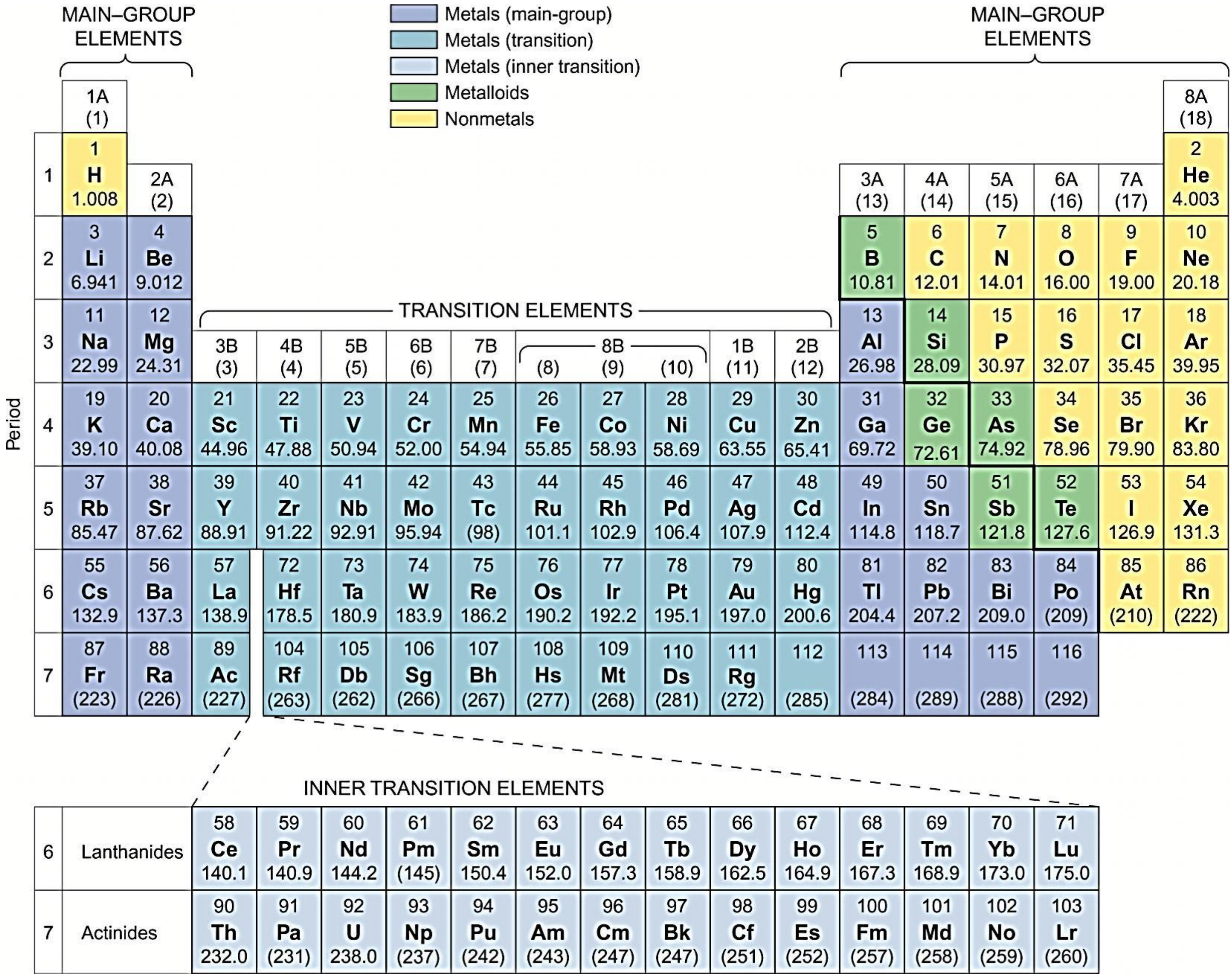
**عام 1871 العالم الروسي ديمتري مندليف نظم هذه المعلومات في جدول والذي فيه درج العناصر من خلال زيادة العدد الكتلي حسب تشابه خواصها الكيميائية في كل عمود.**

**اما الجدول الدوري الحديث للعناصر فقد اعتمد تنظيم الذرات على زيادة العدد الذري للعناصر وليس العدد الكتلي ويتلخص تنظيم الجدول بالآتي:-**

1. **كل عنصر له صندوق يحتوي على العدد الذري ورمز العنصر والعدد الكتلي والصناديق تترتب وفقاً لزيادة العدد الذري من اليسار الى اليمين.**
2. **تنتظم الصناديق الى شبكة من الدورات او الصفوف الافقية ومجاميع عمودية.**

   **وكل دورة لها رقم من 1-7 وكل مجموعة من 1-8 ومقسمة الى A و B**
3. **المجاميع العموديه الثمانية نوع A اثنان منها على اليسار وستة على اليمين تحتوي على المجاميع الرئيسة .**

   **والمجاميع العشرة نوع B تحتوي على العناصر الانتقالية.**




**At this point in the text, the clearest distinction among the elements is their classification as metals, nonmetals, or metalloids. The "staircase" line that runs from the top of Group 3A(13) to the bottom of Group 6A(16) in Period 6 is a dividing line for this classification. The metals (three shades of blue) appear in the large lower-left portion of the table.**

**About three-quarters of the elements are metals, including many main-group elements and all the transition and inner transition elements. They are generally shiny solids at room temperature (mercury is the only liquid) that conduct heat and electricity well and can be tooled into sheets (malleable) and wires (ductile). The nonmetals (yellow) appear in the small upper-right portion of the table. They are generally gases or dull, brittle solids at room temperature (bromine is the only liquid) and conduct heat and electricity poorly. Along the staircase line lie the metalloids (green; also called semimetals), which have properties between those of metals and nonmetals. Several metalloids, such as silicon (Si) and germanium (Ge), play major roles in modern electronics.**

**It is important to learn some of the group (family) names. Group 1A(1), except for hydrogen, consists of the *alkali metals,* and Group 2A(2) consists of the *alkaline earth metals.* Both groups consist of highly reactive elements. The *halogens,* Group 7A(17), are highly reactive nonmetals, whereas the *noble gases,***

**Group 8A(18), are relatively unreactive nonmetals. Other main groups [3A(13) to 6A(16)] are often named for the first element in the group; for example, Group 6A is the *oxygen family*.**

**A key point that we return to many times is that, in general, elements in a group have similar chemical properties and elements in a period have different chemical properties.**

## Quantum Numbers of an Atomic Orbital

**When the atom absorbs energy, it exists in an excited state and the region of space occupied by the electron is described by a different atomic orbital.**

**اعداد الكم للاوربيتال الذري**

**عندما تمتص الذرة طاقة معينة، فأنها تتواجد بحالة التهيج ويتمثل مليء الحيز الفضائي بالالكترون من خلال اوربيتالات ذرية متعددة.**

**An atomic orbital is specified by three quantum numbers. One is related to the orbital's size, another to its shape, and the third to its orientation in space*.**

**The quantum numbers have a hierarchical relationship: the size-related number limits the shape-related number, which limits the orientation-related number. Let's examine this hierarchy and then look at the shapes and orientations.**

**1. The principal quantum number (*n*) *is a positive integer* (1, 2, 3, and so forth). It indicates the relative *size* of the orbital and therefore the relative *distance from the nucleus* of the peak in the radial probability distribution plot. The principal quantum number specifies the *energy level* of the**

**H atom:** ***the higher the n value, the higher the energy level.*** **When the electron occupies an orbital with $n$ =1, the H atom is in its ground state and has lower energy than when the electron occupies the $n$ = 2 orbital (first excited state).**

**2. The angular momentum quantum number ($l$) *is an integer from* 0 *to* $n$ - 1. It is related to the *shape* of the orbital and is sometimes called the *orbital-shape.* Note that the principal quantum number sets a limit on the values for the angular momentum quantum number; that is, $n$ limits $l$. For an orbital with $n$ = 1, $l$ can have a value of only 0. For orbitals with $n$ = 2, $l$ can have a value of 0 or 1; for those with $n$ = 3, $l$ can be 0, 1, or 2; and so forth. Note that the number of possible $l$ values equals the value of $n$.**

**3. The magnetic quantum number ($m_l$) *is an integer from* $-l$ *through* 0 *to*$+l$. It prescribes the *orientation* of the orbital in the space around the nucleus and is sometimes called the *orbital-orientation quantum number.* The possible values of an orbital's magnetic quantum number are set by its angular momentum quantum number; that is, $l$ sets the possible values of $m_l$. An orbital with $l$ = 0 can have only $m_l$ = 0. However, an orbital with $l$= 1 can have any one of three $m_l$ values, -1, 0, or +1; thus, there are three possible orbitals with $l$ = 1, each with**

its own orientation. Note that the number of possible $m_l$ values *equals* the number of orbitals, which is $2l + 1$ for a given $l$ value.

The following Table summarizes the hierarchy among the three quantum numbers. (the falling and, we'll discuss a fourth quantum number that relates to a property of the electron itself.) The total number of orbitals for a given $n$ value is $n^2$.

الاوربيتال الذري يتصف من خلال ثلاث اعداد كم، احدهما له علاقة بالحجم والاخر للشكل والثالث للتوزيع في الفضاء.

1- عدد الكم الرئيسي (n) هو عدد صحيح موجب (3,2,1..... وهكذا) ويمثل الحجم النسبي للاوربيتال من خلاله المسافة النسبية عن النواة.

2- عدد الكم للزخم الزاوي (*l*) تكون قيمته من صفر الى n-1، وله علاقة بشكل الاوربيتال.

3- عدد الكم المغناطيسي (m*l*) وهو عدد صحيح تكون قيمته من *l*– ثم صفر ثم +*l* .

**Table 7.2** The Hierarchy of Quantum Numbers for Atomic Orbitals

| Name, Symbol (Property) | Allowed Values | Quantum Numbers | | | | | |
|---|---|---|---|---|---|---|---|
| Principal, $n$ (size, energy) | Positive integer (1, 2, 3, . . .) | 1 | 2 | | 3 | | |
| Angular momentum, $l$ (shape) | 0 to $n - 1$ | 0 | 0 | 1 | 0 | 1 | 2 |
| Magnetic, $m_l$ (orientation) | $-l, \ldots, 0, \ldots, +l$ | 0 | 0 | −1 0 +1 | 0 | −1 0 +1 | −2 −1 0 +1 +2 |

## Determining Quantum Numbers for an Energy Level

***Problem* What values of the angular momentum (*l*) and magnetic (*ml*) quantum numbers are allowed for a principal quantum number (*n*) of 3? How many orbitals exist for *n* = 3? *Plan* We determine allowable quantum numbers with the rules from the text: *l* values are integers from 0 to *n* - 1, and *ml* values are integers from -*l* to 0 to +*l.* One *ml* value is assigned to each orbital, so the number of *ml* values gives the number of orbitals.**

**Solution** Determining $l$ values: for $n = 3$, $l = 0, 1, 2$

Determining $m_l$ for each $l$ value:

$$\text{For } l = 0, \quad m_l = 0$$

$$\text{For } l = 1, \quad m_l = -1, 0, +1$$

$$\text{For } l = 2, \quad m_l = -2, -1, 0, +1, +2$$

There are nine $m_l$ values, so there are nine orbitals with $n = 3$.

**The total number of orbitals for a given n value is $n^2$, and for $n = 3$, $n^2 = 9$.**

**Home work Specify the *l* and $m_l$ values for *n* = 4.**

**The energy states and orbitals of the atom are described with specific terms and associated with one or more quantum numbers:**

**1. *Level.* The atom's energy levels, or *shells,* are given by the *n* value: the smaller the *n* value, the lower the energy level and the greater the probability of the electron being closer to the nucleus.**

**2. *Sublevel.* The atom's levels contain sublevels, or *subshells,* which designate the orbital shape. Each sublevel has a letter designation:**

***l* = 0 is an *s* sublevel.**
***l* = 1 is a *p* sublevel.**
***l* = 2 is a *d* sublevel.**
***l* = 3 is an *f* sublevel.**

**Sublevels with *l* values greater than 3 are designated alphabetically: *g* sublevel, *h* sublevel, etc.) Sublevels are named by joining the *n* value and the letter designation. For example, the sublevel (subshell) with *n*= 2 and *l* = 0 is called the 2*s* sublevel.**

**3. *Orbital.* Each allowed combination of *n*, *l*, and *ml* values specifies one of the atom's *orbitals.* Thus, the three quantum numbers that describe an orbital express its size (energy), shape, and spatial orientation. You can easily give the quantum numbers of the orbitals in any sublevel if you know the sublevel letter designation and the quantum number hierarchy. For example, the 2*s* sublevel has only one orbital, and its quantum numbers are $n = 2$, $l = 0$, and $m_l = 0$. The 3*p* sublevel has three orbitals: one with $n = 3$, $l = 1$, and $m_l = -1$; another with $n = 3$, $l = 1$, and $m_l = 0$; and a third with $n = 3$, $l = 1$, and $m_l = +1$.**

**حالات الطاقة والاوربيتالات للذرة يمكن وصفها من خلال حالات محددة متعلقة بأحد أو اكثر من اعداد الكم.**

**Determining Sublevel Names and Orbital Quantum Numbers**

***Problem*** **Give the name, magnetic quantum numbers, and number of orbitals for each sublevel with the given quantum numbers:**

**(a) $n$ = 3, $l$ = 2 (b) $n$ = 2, $l$ = 0 (c) $n$ = 5, $l$ = 1 (d) $n$ = 4, $l$ = 3**

*Solution*

| | $n$ | $l$ | Sublevel Name | Possible $m_l$ Values | No. of Orbitals |
|---|---|---|---|---|---|
| (a) | 3 | 2 | $3d$ | −2, −1, 0, +1, +2 | 5 |
| (b) | 2 | 0 | $2s$ | 0 | 1 |
| (c) | 5 | 1 | $5p$ | −1, 0, +1 | 3 |
| (d) | 4 | 3 | $4f$ | −3, −2, −1, 0, +1, +2, +3 | 7 |

***Check*** **Check the number of orbitals in each sublevel using**

**No. of orbitals = no. of *ml* values = 2*l* + 1**

**Home work What are the *n*, *l*, and possible $m_l$ values for the 2*p* and 5*f* sublevels?**

**Identifying Incorrect Quantum Numbers**

**Problem What is wrong with each of the following quantum number designations and/or sublevel names?**

| | $n$ | $l$ | $m_l$ | Name |
|---|---|---|---|---|
| (a) | 1 | 1 | 0 | $1p$ |
| (b) | 4 | 3 | +1 | $4d$ |
| (c) | 3 | 1 | −2 | $3p$ |

***Solution*** **(a) A sublevel with $n = 1$ can have only $l = 0$,not $l = 1$. The only possible sublevel name is 1*s***

**(b) A sublevel with $l = 3$ is an *f* sublevel, not a *d* sublevel. The name should be 4*f***

**(c) A sublevel with $l = 1$ can have only $m_l$ of -1,0,+1, not -2.**

***Check*** **that $l$ is always less than $n$, and $m_l$ is always $\geq -l$ and $\leq +l$.**

**Shapes of Atomic Orbitals**

**Each sublevel of the H atom consists of a set of orbitals with characteristic shapes..**

**The *s* Orbital An orbital with $l = 0$ has a *spherical* shape with the nucleus at its center and is called an *s* orbital.**

**اشكال الاوربيتالات الذرية:-**

**اوربيتال s:- هو الاوربيتال الذي له قيمة $l$=0 ويكون شكله كروي والنواة في المركز.**

**The *p* Orbital An orbital with $l = 1$, called a *p* orbital, has two regions (lobes) of high probability, one on *either side* of the nucleus. Thus, the *nucleus lies at the nodal plane* of this dumbbell-shaped orbital.**

**The maximum value of $l$ is $n - 1$, so only levels with $n = 2$ or higher can have a *p* orbital. Therefore, the lowest energy *p* orbital (the one closest to the nucleus) is the 2*p*. Keep in mind that *one p orbital consists of both lobes* and that the electron spends *equal* time in both. Similar to the pattern for**

**$s$ orbitals, a 3$p$ orbital is larger than a 2$p$ orbital, a 4$p$ orbital is larger than a 3$p$ orbital, and so forth.**

**Unlike an $s$ orbital, each $p$ orbital *does* have a specific orientation in space. The $l$ = 1 value has three possible $m_l$ values: -1, 0, and _1, which refer to three *mutually perpendicular* $p$ orbitals. They are identical in size, shape, and energy, differing only in orientation. For convenience, we associate $p$ orbitals with the $x$, $y$, and $z$ axes (but there is no necessary relation between a spatial axis and a given $m_l$ value): the $p_x$ orbital lies along the $x$ axis, the $p_y$ along the $y$ axis, and the $p_z$ along the $z$ axis.**

**The $d$ Orbital An orbital with $l$ = 2 is called a $d$ orbital. There are five possible $m_l$ values for the $l$ = 2 value: -2, -1, 0, +1, and +2. Thus, a $d$ orbital can have any one of five different orientations, . Four of the five $d$ orbitals have four lobes (a cloverleaf shape) prescribed by two mutually perpendicular nodal planes, with the nucleus lying at the junction of the lobes. Three of these orbitals lie in the mutually perpendicular $xy$, $xz$, and $yz$ planes, with their lobes *between* the axes, and are called the $d_{xy}$, $d_{xz}$, and $d_{yz}$ orbitals. A fourth, the orbital, also lies in the $xy$ plane, but its lobes are directed *along* the axes. The fifth $d$ orbital, the , has a different shape: two major lobes lie along the $z$ axis, and a donut-shaped region girdles the center. An electron**

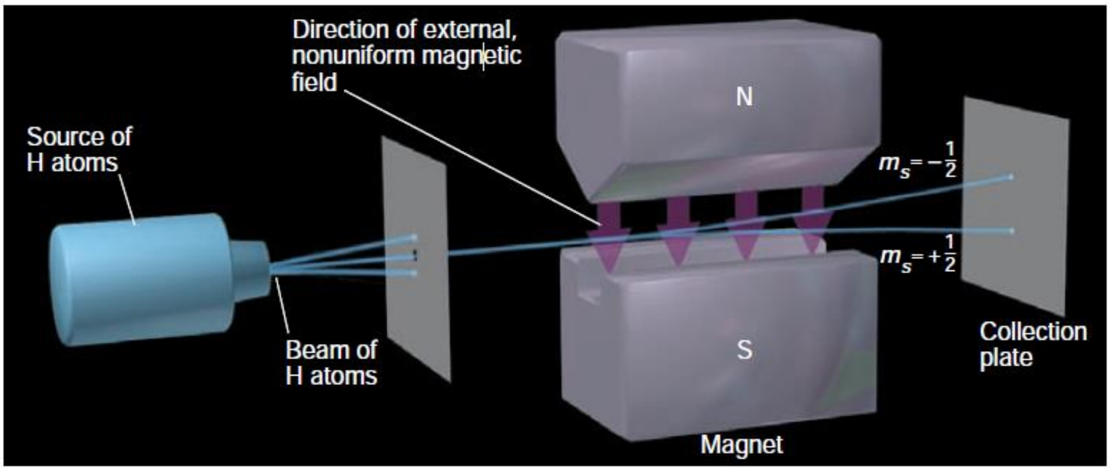
associated with a given *d* orbital has equal probability of being in any of the orbital's lobes.

- اوربيتال *P* :- هو الاوربيتال الذي له قيمة $l$=1 ، ويكون له فصين وتواجد الالكترون فيه باحتمالية عالية، وكل فص على جانب من النواة.

والقيمة العظمى الى *l* هي *n-l* .

كل اوربيتال من نوع *P* له توزيع خاص بالفراغ ومتوزعة على المحاور الثلاثة.

- اوربتال *d* :- هنا قيمة $l = 2$ وهناك خمسة احتمالات لقيمة *ml* هنا.




**The Electron-Spin Quantum Number: As we said that the three quantum numbers *n, l,* and *ml* describe the size (energy), shape, and orientation, respectively, of an atomic orbital. However, an additional quantum number is needed to describe a property of the electron itself, called *spin,* which is not a property of the orbital. Electron spin becomes important when more than one electron is present. Like charge, spin is an intrinsic property of the electron, and the spin quantum number (*ms*) has values of either +$\frac{1}{2}$ or -**

$\frac{1}{2}$. **Thus, *each electron in an atom is described completely by a set of four quantum numbers: the first three describe its orbital, and the fourth describes its spin.* The quantum numbers are summarized in Table.**

**Table Summary of Quantum Numbers of Electrons in Atoms**

| Name | Symbol | Permitted Values | Property |
|---|---|---|---|
| Principal | $n$ | Positive integers (1, 2, 3, ...) | Orbital energy (size) |
| Angular momentum | $l$ | Integers from 0 to $n - 1$ | Orbital shape (The $l$ values 0, 1, 2, and 3 correspond to $s$, $p$, $d$, and $f$ orbitals, respectively.) |
| Magnetic | $m_l$ | Integers from $-l$ to 0 to $+l$ | Orbital orientation |
| Spin | $m_s$ | $+\frac{1}{2}$ or $-\frac{1}{2}$ | Direction of $e^-$ spin |

**Now we can write a set of four quantum numbers for any electron in the ground state of any atom. For example, the set of quantum numbers for the lone electron in hydrogen (H; *Z* = 1) is *n* = 1, *l* = 0, *ml* = 0, and $m_s$ =+$\frac{1}{2}$. (The spin quantum number for this electron could just as well have been -$\frac{1}{2}$ , but by convention, we assign +$\frac{1}{2}$ for the first electron in an orbital.)**

**عدد الكم البرم الالكتروني :-**

**كما تبين هناك ثلاث اعداد كم *ml, l, n* تصف الحجم والشكل والتوزيع للاوربيتال الذري، وهنا عدد كم اضافي مطلوب لوصف صفات الالكترون نفسه من حيث البرم الالكتروني ويأخذ الرمز $m_s$ وله قيمة $\frac{1}{2}$ + او $\frac{1}{2}$ - .**

**وعليه كل الكترون في الذرة يمكن وصفه كلياً من خلال سيت من اربعة اعداد كم، ثلاثة منها تصف اوربيتاله والرابع يصف برم الكترون.**

## The Exclusion Principle

**The Austrian physicist Wolfgang Pauli formulated the exclusion principle: *no two electrons in the same atom can have the same four quantum numbers.* That is, each electron must have a unique "identity" as expressed by its set of quantum numbers. Therefore, the second He electron occupies the same orbital as the first but has an opposite spin: $n = 1$, $l = 0$, $m_l = 0$, and $ms = -\frac{1}{2}$ .**

**مبدأ الاقصاء**

**العالم باولي اسس هنا الى مبدأ سمي بمبدأ الاقصاء وهو: لا يوجد الكترونين في نفس الذرة لها ذات اعداد الكم الرابعة.**

**Here are two common ways to designate the orbital and its electrons:**

**1. *The electron configuration.* This shorthand notation consists of the principal energy level (*n* value), the letter designation of the sublevel (*l* value), and the number of**

**electrons (#) in the sublevel, written as a superscript: *nl*$^{\#}$ . The electron configuration of H is 1*s*1 (spoken "one-ess-one"); that of He is 1*s*$^2$ (spoken "one-ess-two," *not* "one-ess-squared"). This notation does *not* indicate electron spin but assumes you know that the two 1*s* electrons have paired (opposite) spins.**

**2. *The orbital diagram.* An orbital diagram consists of a box (or circle, or just a line) for each orbital in a given energy level, grouped by sublevel, with an arrow indicating an electron *and* its spin . ( up is + $\frac{1}{2}$ and down is - $\frac{1}{2}$ . )**

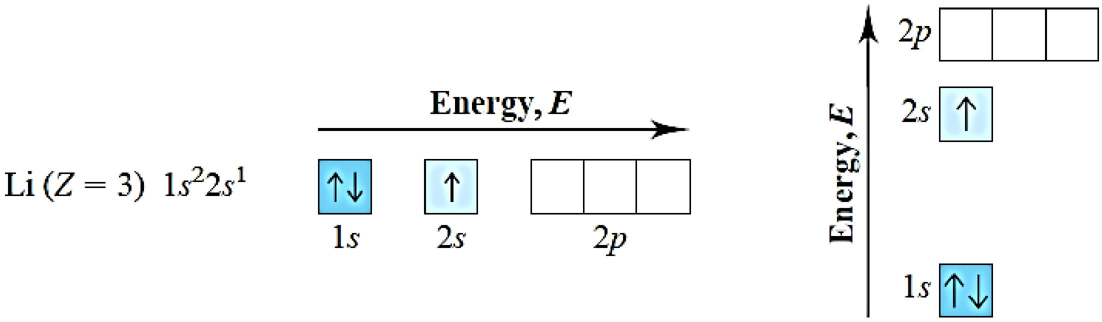
**Throughout the text ,**

**orbital occupancy is also indicated by color intensity: an orbital with no color is empty, pale color means half-filled, and full color means filled.) The electron configurations and orbital diagrams for the first two elements are**

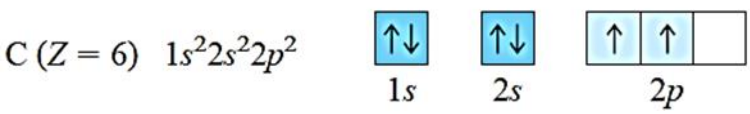
$$\mathrm{H}\ (Z = 1)\quad 1s^1\quad \underset{1s}{\boxed{\uparrow}} \qquad\qquad \mathrm{He}\ (Z = 2)\quad 1s^2\quad \underset{1s}{\boxed{\uparrow\downarrow}}$$

**The exclusion principle tells us that an orbital can hold only two electrons, so the 1*s* orbital in He is filled, and the *n* = 1 level is also filled. The *n* = 2 level is filled next, beginning with the 2*s* orbital, the next lowest in energy.**

**As we said earlier, the first two electrons in Li fill the 1*s* orbital, and the last added Li electron has quantum numbers *n* = 2, *l* = 0, *ml* = 0, *ms* =+ $\frac{1}{2}$. The electron configuration for Li is $1s^2 2s^1$. Note that the orbital diagram shows all the orbitals for *n* = 2, whether or not they are occupied:**

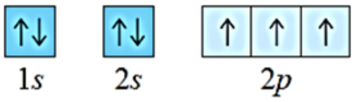



**To minimize electron-electron repulsions, the last added (sixth) electron of carbon enters one of the unoccupied 2p orbitals; by convention, we place it in the ml = 0 orbital. Experiment shows that the spin of this electron is parallel to (the same as) the spin of the other 2p electron: n = 2, l = 1, . ml = 0, ms =+ $\frac{1}{2}$**



**This placement of electrons for carbon exemplifies Hund's rule: when orbitals of equal energy are available, the electron configuration of lowest energy has the maximum number of unpaired electrons with parallel spins. Based on Hund's rule, nitrogen's seventh electron enters the last empty 2p orbital, with its spin parallel to the two other 2p electrons: n = 2, l = 1, ml = +1 , ms=+** $\frac{1}{2}$

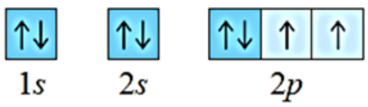
N ($Z = 7$) $1s^2 2s^2 2p^3$




**The eighth electron in oxygen must enter one of these three half-filled 2p orbitals and "pair up" with (have opposing spin to) the electron already present. With the 2p orbitals all having the same energy, we place the electron in the orbital previously designated ml = -1. The quantum numbers are :**

**n = 2, l = 1 , ml = -1 , ms= -** $\frac{1}{2}$

O ($Z = 8$) $1s^2 2s^2 2p^4$



## Group and Period Numbers :

**Key information is embedded in the periodic table:**

**1.Among the main-group elements (A groups), *the group number equals the number of outer electrons* (those with the highest *n*): chlorine (Cl; Group 7A) has 7 outer electrons, tellurium (Te; Group 6A) has 6, and so forth**

***2.The period number is the n value of the highest energy level.* Thus, in Period 2, the *n* = 2 level has the highest energy; in Perio.d 5, it is the *n* =5 level**

**3.The n value squared ($n^2$) gives the total number of orbitals in that energy level.**