# *AP Chemistry*

*Atomic Hotels*

# Learning Objectives:

1) Define the Aufbau principle, Pauli Exclusion Principle, and Hund's Rule
2) List and describe the four quantum numbers

3) Count valence electrons

4) Write electron configurations

*Textbook Reading*: Sections 6.7-6.9

*Group roles*: A Leader; B Recorder; C Reporter

# Part 1: The Atomic Hotel[[1]](#footnote-1)

**I.** The Atomic Hotel is a special hotel designed for electrons. The hotel has a strict policy called the Aufbau principle, which states that "ground" floors must be filled first *and in order*. It costs more to get rooms on higher floors. In the atomic world, energy is money, so "excited" electrons get rooms on higher floors, resulting in an exception to hotel policy.

Looking back through the old guest logs, the following layouts can be sketched. Determine which electrons had more "money.” Label those electrons as excited.

May 23, 1998

June 19, 1999

September 10, 1991

**A**

**B**

**C**

**II.** Another policy that the hotel enforces is called the Pauli Exclusion Principle. It was determined in 1925 that electrons can occupy the same room, but only if they have opposite spins, so they do not interfere with one another.

Which electrons below did not follow the Pauli exclusion principle?

December 1, 2000

April 2, 1995

July 4, 1988

**A**

**B**

**C**

1. The Pauli Exclusion Principle serves to identify each electron. Four numbers (n, ℓ, mℓ, and ms) are assigned to each guest in the hotel. The number n, is the principle quantum number , which corresponds to the "floor" the electron is on. The letter ℓ describes the room layout or the "floor area" in which the electron is staying (s = 0, p = 1, d = 2, etc.). There is only one s type room on each floor; there are three p type rooms on each floor from the second up; there are five d type rooms on each floor starting with the third floor and going up; and there are seven f type rooms on each floor starting with the fourth floor and moving upwards. The letter mℓ describes the specific room (most analogous to a room number). Figure 1 shows a diagram of the hotel rooms available by floor.

**Figure 1: The Atomic Hotel by Floor**

s

f

d

p

Floor **n** = 1, 2, 3….

Room type ℓ

 s = 0

 p = 1

 d = 2

 f = 3

**m**ℓ specific room

4

-2 -1 0 +1 +2

-1 0 +1

0

-3 -2 -1 0 +1 +2 +3

3

-2 -1 0 +1 +2

-1 0 +1

0

2

-1 0 +1

0

1

0

The preferred hotel diagram is one which shows the hotel rooms by cost (which, as stated in part I is the also the order in which the rooms are filled). Generally, the most inexpensive rooms are on the first floor, with prices increasing with floor. Note that d rooms are more expensive than the s or p rooms on the next floor. Electrons can pair up in a single room, so the hotel has to have a way of identifying each one separately. This is done with ms, the spin quantum number which is +½ or -½.

4f

-3 - 2 -1 0 +1 +2 +3

0

6s

5p

-1 0 +1

4d

5s

-2 -1 0 +1 +2

0

4p

-1 0 +1

3d

**NOTE:** d and f suites are more expensive than the s rooms on the next floor/s

(3d > 4s).

-2 -1 0 +1 +2

4s

0

3p

-1 0 +1

**Example:** an electron with the numbers 3, 0, 0, ½ is staying on the 3rd floor, in section s, in room #0, and is in + ½ spin state.

3s

0

2p

-1 0 +1

2s

0

1s

0

Using the above pattern, identify the circled electrons using the four quantum numbers.

March 9, 1992

\_\_ \_\_ \_\_ \_\_

 n ℓ mℓ  ms

**A**

August 22, 1994

\_\_ \_\_ \_\_ \_\_

 n ℓ mℓ  ms

**B**

January 17, 1980

**C**

\_\_ \_\_ \_\_ \_\_

 n ℓ mℓ  ms

**IV.** There is one more policy that helps the hotel run smoothly and keep customers happy. Hund's Rule states that if electrons are being placed in the same section of a floor (rooms that cost the same) then each one gets their own room and has the same spin until the floor is half-filled. If any more electrons want to stay in that same section, then they must pair up with another electron and assume the opposite spin. This does not necessarily apply to electrons that have purchased more expensive rooms.

In the diagrams below identify the areas in which Hund's Rule was broken. Describe how the rule is being broken in each case.

**C**

**B**

**A**

July 10, 1983

November 26, 1995

February 12, 1997

Additionally, the hotel floor (n, the principal quantum number) gives some additional information:

n = maximum number of sublevels on a floor (i.e., types of rooms/orbitals)

n2 = maximum number of rooms on a floor (number of orbitals in an energy level)

2n2 = maximum number of electrons that can occupy a floor

**V.** OBSERVATIONS:

A. How many "rooms" are there in an "s" suite of a floor? \_\_\_\_\_

B. How many "rooms" are there in a "p" suite of a floor? \_\_\_\_\_

C. How many "rooms" are there in a "d" suite of a floor? \_\_\_\_\_

 D. How many electrons can stay on the first floor? \_\_\_\_\_

 second floor? \_\_\_\_\_

 third floor? \_\_\_\_\_

E. Describe how the rooms in each section are numbered.

F. In diagram C (Section IV above), describe why the electron could go into the 4s

 orbital instead of the 3p.

G. Why might section 3d fall between section 4s and 4p?

 Write out the electron configurations for each of the following elements:

B

N

F

Na

Identify the atoms whose atomic hotels were drawn in IC, IIB, IIIA, IIIB, IIIC, and IVB

**Part II: Valence electrons**

**Valence electrons** are the electrons in an atom’s highest occupied shell (s and p electrons) and in *partially filled* subshells of lower shell d or f electrons. Note that this is a more nuanced definition than we used last year in Honors Chemistry.

*Example 1*: K (potassium) has the electron configuration 1s22s22p63s23p64s1 Its highest occupied shell is 4 and it has one electron in the 4s orbital, so it has one valence electron.

*Example 2*: S (sulfur) has the electron configuration 1s22s22p63s23p4. Its highest occupied shell is 3 and it has two electrons in the 3s orbital and four electrons in the 3p orbital. Sulfur has six total valence electrons.

*Example 3*: Co (cobalt) has the electron configuration 1s22s22p63s23p64s23d7. Its highest occupied shell is 4 and it has two electrons in the 4s orbital. Cobalt also has 7 electrons in a partially filled 3d orbital so it has a total of nine valence electrons.

*Example 4*: Se (selenium) has the electron configuration 1s22s22p63s23p64s23d104p4. Its highest occupied shell is 4. Selenium has two electrons in the 4s orbital and four electrons in the 4p orbital. Selenium has a full 3d orbital so these ten electrons are NOT valence electrons. Selenium has six total valence electrons.

How many valence electrons do the following elements have?

 F \_\_\_\_\_ Mo \_\_\_\_\_

 Sb \_\_\_\_\_ Rb \_\_\_\_\_

 Nd \_\_\_\_\_ Ag \_\_\_\_\_

Electron configurations can get cumbersome (think about the 107 electrons in bohrium). They can be abbreviated using the noble gas (group 18) notation to represent the core electrons.

*Example1:*Mg has the electron configuration: **1s22s22p6**3s2; Ne has the electron configuration **1s22s22p6**

The electron configuration of Mg can be abbreviated: [Ne] 3s2

*Example 2:*Ru **1s22s22p63s23p64s23d104p6**5s24d6 which can be abbreviated: [Kr]5s24d6

Using the noble gas notation, write the electron configurations for:

P

Sr

Co

As

1. Taken directly from NC State’s Scale-Up chemistry (http://scale-up.ncsu.edu/) [↑](#footnote-ref-1)