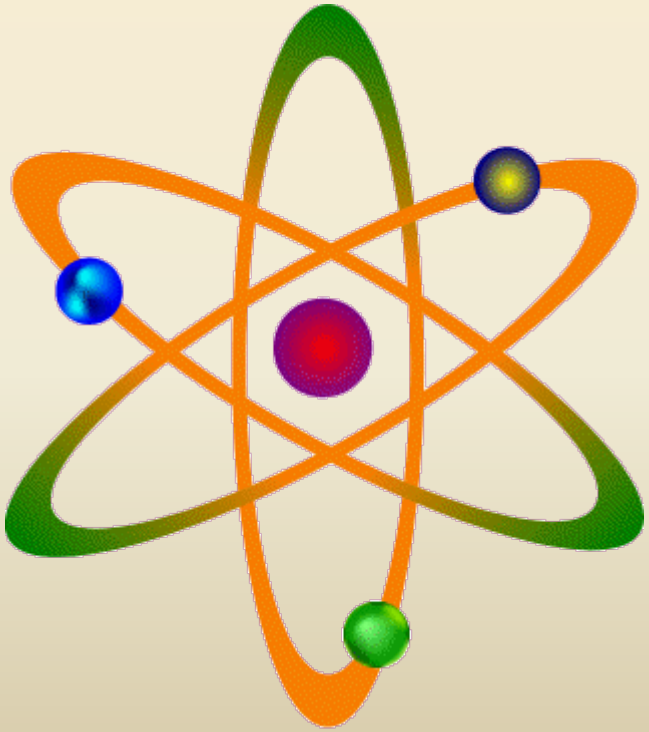
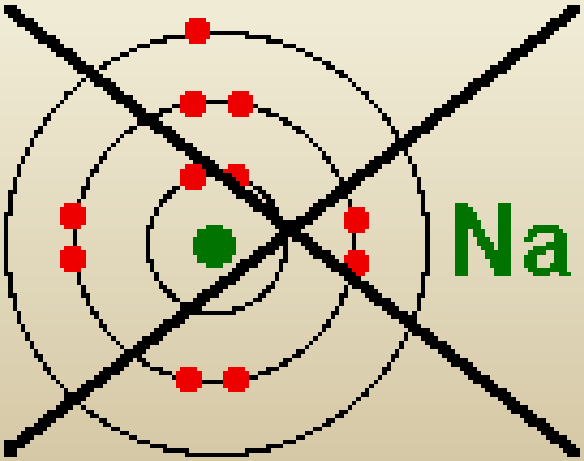
Electron Configurations



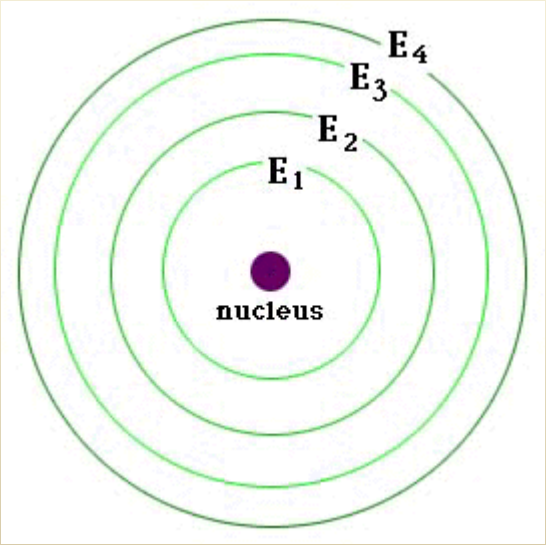
Electron Arrangement in an Atom

- The arrangement of electrons in an atom is its electron configuration.
- It is impossible to know where an electron is or how fast it is traveling at any given time *(Heisenberg Uncertainty Principle? Walter White?).*
- Models of the atom, such as the Bohr model are very inaccurate (oops!) according to modern atomic theory.
- Atoms and electrons are *more complicated* than planets orbiting the Sun.



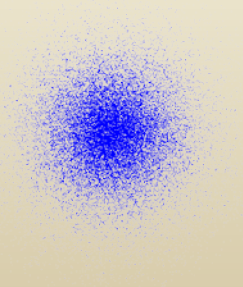
Energy Levels

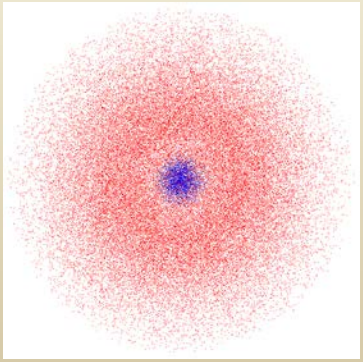
- There are “shells” or energy levels around an atom. The farther away an energy level is from the nucleus, the more energy the sublevel has.



Electron Orbitals

- Orbitals are *clouds of probability* within an energy level, so an actual orbital is a region of space, where an electron might be found.
- Two orbital clouds are pictured below. There are *more dots near the center* of the picture, because an electron is *most likely* to be near the nucleus (center) of the atom (the electron which is negative is attracted to the positive protons).





Types of Orbitals

- Within the energy shells are different shaped orbitals (represented by the letters s, p, d, and f) that can contain different total numbers of electrons. A number can be placed in front of the orbital letter to represent the energy level that an orbital belongs to.

For example: 1s is an s shaped orbital on the 1st energy level, which is closest to the nucleus

Orbitals, con’td

- Different shaped orbitals can hold different numbers of electrons:
  - s orbital can hold up to 2 electrons (1 pair)
  - p orbital can hold up to 6 electrons (3 pairs)
  - d orbitals can hold up to 10 electrons (5 pairs)
  - f orbitals can hold up to 14 electrons (7 pairs)

If a vehicle were an orbital…..

- Match the orbital to the vehicle that most represents it!

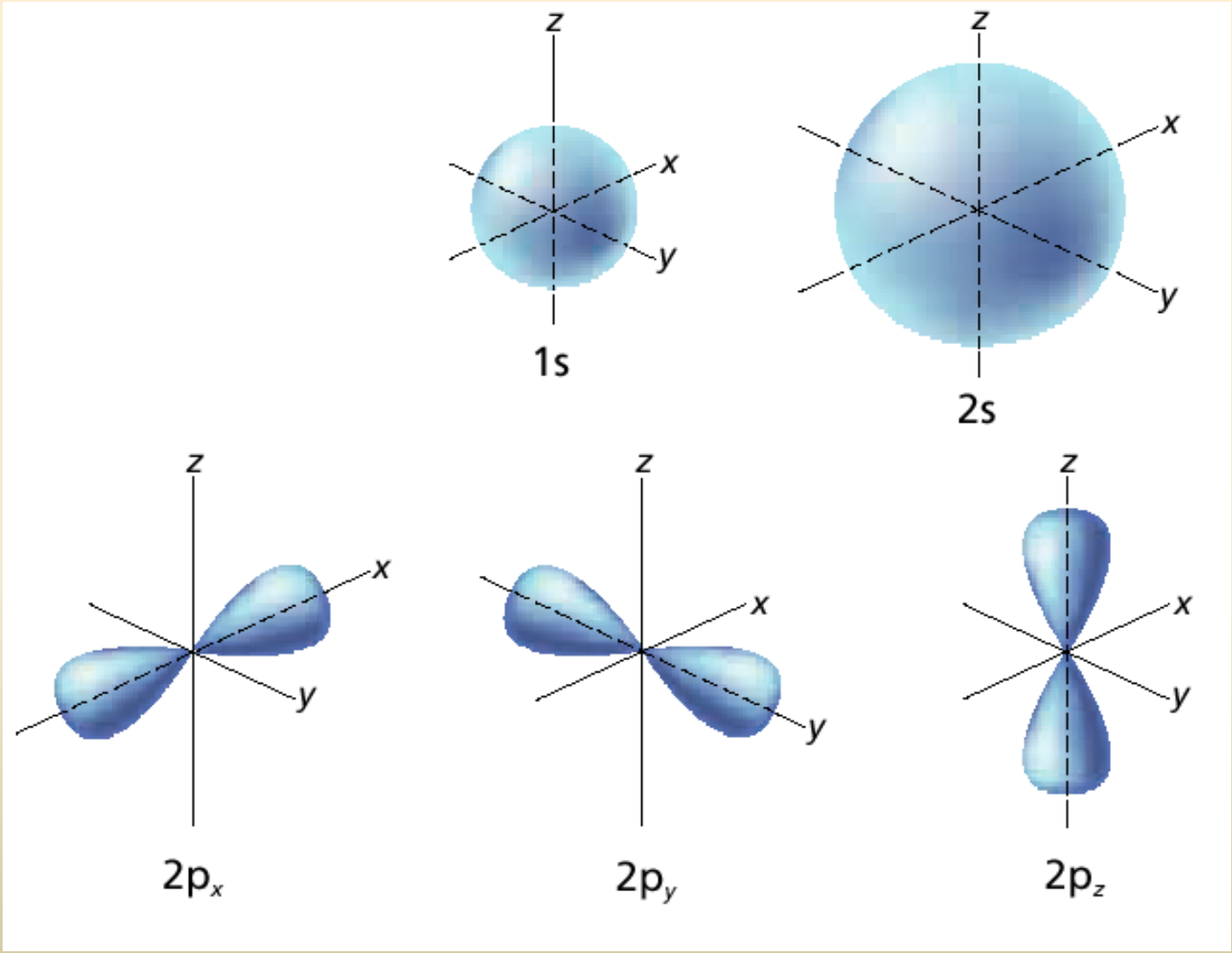




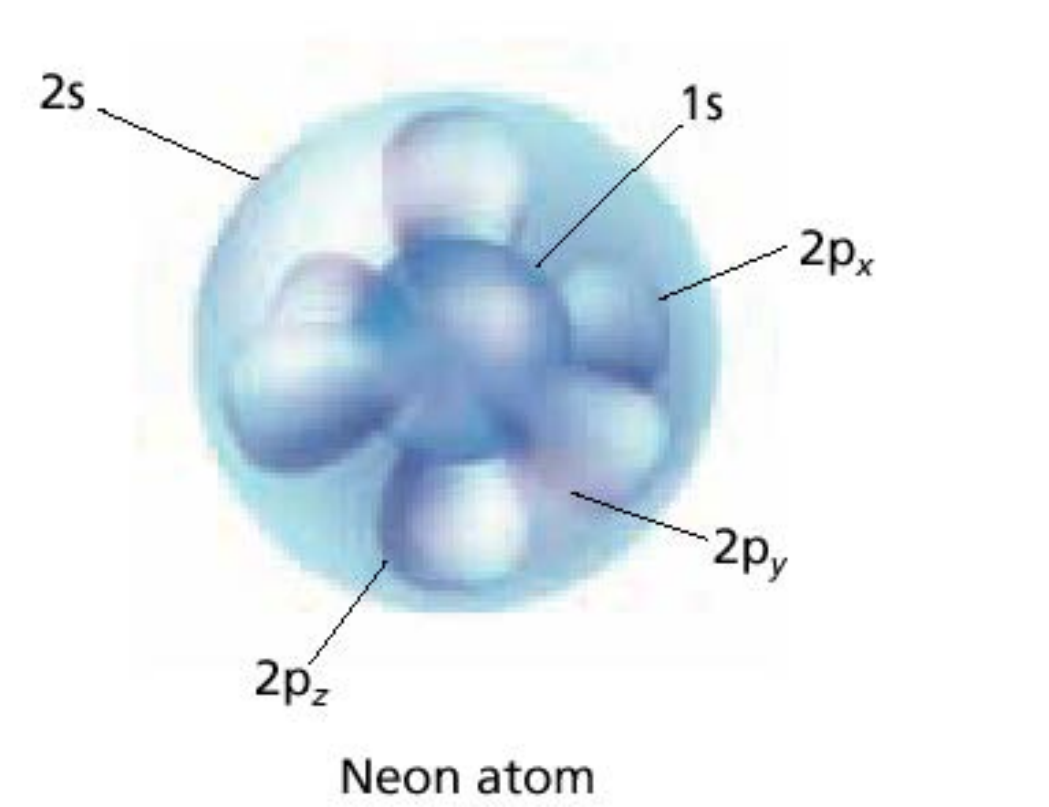




So how do the orbitals REALLY look?

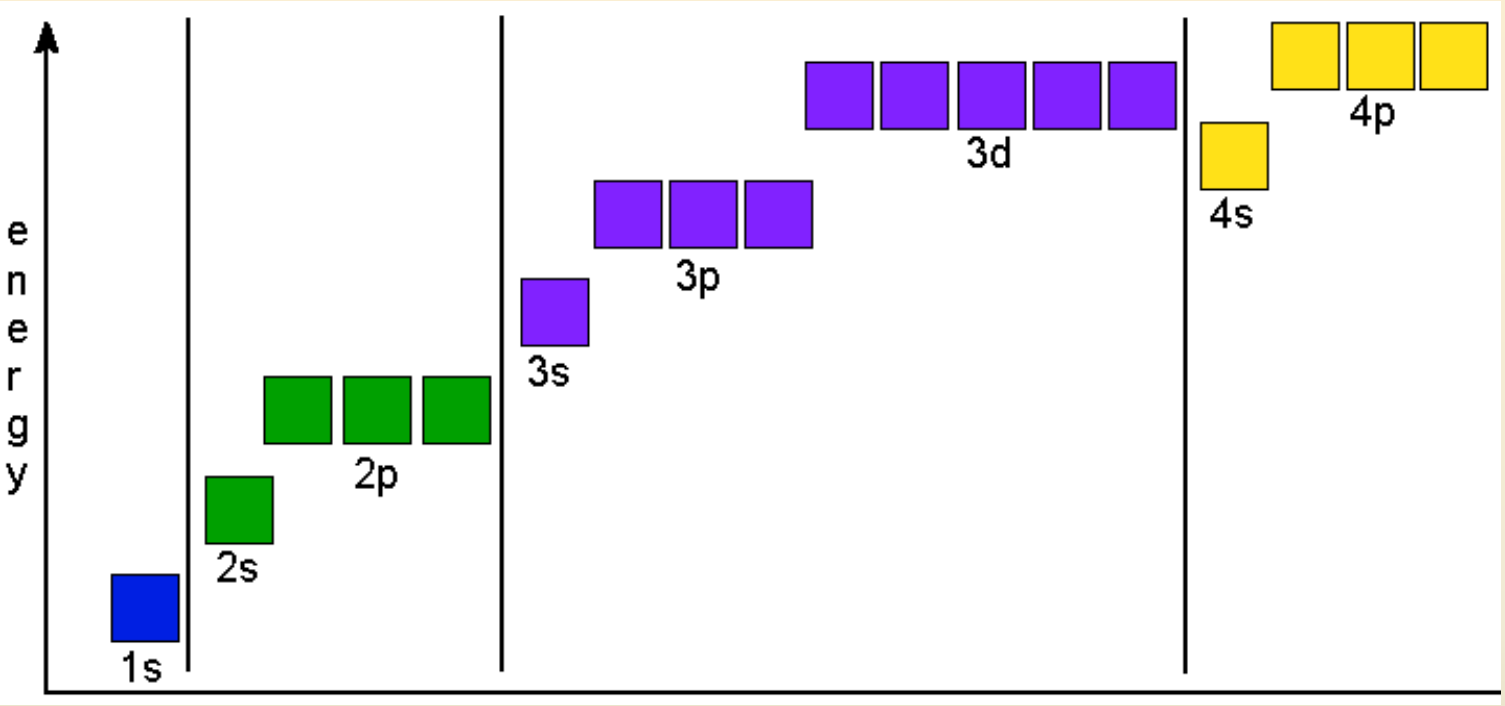


Putting the s and p orbitals together…..



So what number represents the highest energy level as well as the outermost level in this atom of Neon?

Another way to look at it….



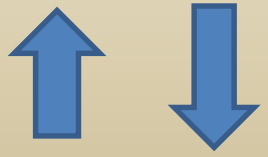
- The boxes represent the different orbitals. As the number of the level increases, the energy increases. Each individual box can hold 2 electrons at a time.

How are electrons in their orbitals like an apartment house?

- Different floors in the apartment represent different energy levels or shells.
- Each room on each floor of the apartment house corresponds to an orbital, or one box from the previous diagram.

How are electrons in their orbitals like an apartment house?

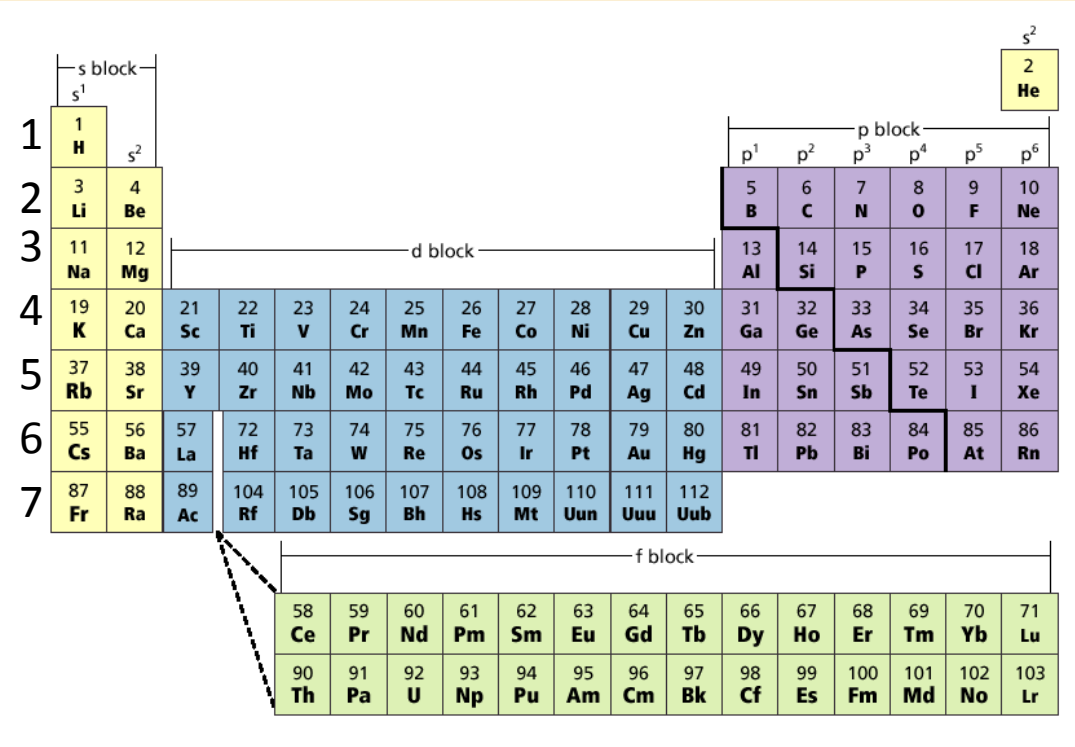
- Different floors in the apartment represent different energy levels or shells.
- Each room on each floor of the apartment house corresponds to an orbital, or one box from the previous diagram.
- Each room on each floor can hold up to 2 people (the electrons), and each room is filled with one person first before the rooms become double occupancy.
- Only a man and a woman can live together in a room in the apartment house. (this represents the "spin" of the electrons – one has an up-spin, the other has a down-spin)

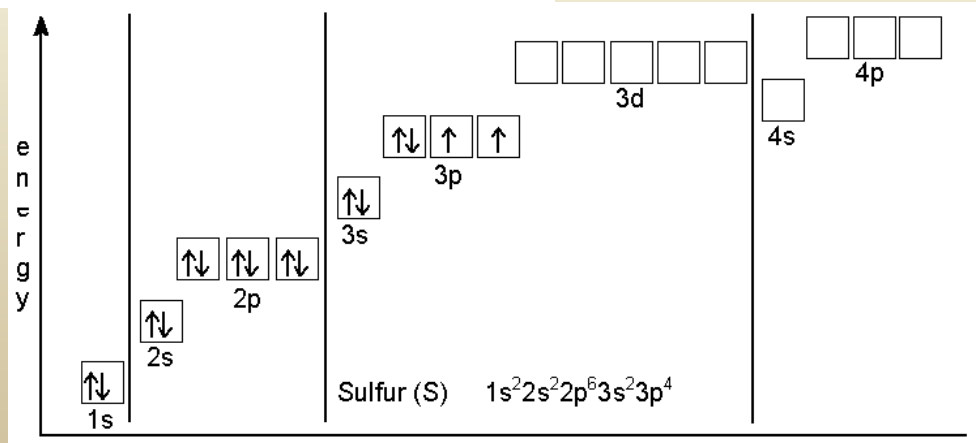


Who figured this out and how does it relate to the apartment analogy?!?

Apartment House Rules	Electron Rules
From the Bottom Up: Rooms must be filled from the ground floor up. Fill the one room on the first floor before starting to put new tenants on the second floor. Then fill the s room before the p rooms. At higher floors the order might change a bit.	**Aufbau Principle**: the electrons fill the available orbitals from lowest energy to highest energy. In the ground state all the electrons are in the lowest possible energy level.
Singles First: the owner of the building wants to have the tenants spread out as much as possible. For that reason singles are placed in rooms before couples. If couples must be placed into a room then all of the other rooms on that floor must already have a single in them.	**Hund's Rule:** The electrons must be placed into the orbitals in such a way that no pairs are put together unless absolutely necessary. That is, single electrons must be placed into boxes first and then paired up if necessary.
Opposite "Gender" Only: When two people are placed in a room they must be of opposite genders. No men may room together and no women may room together. This is an arbitrary rule on the part of the owners: in a just world we wouldn't have to follow it. But quantum mechanics has nothing to do with justice.	**Pauli Exclusion Principle**: Electrons come in two varieties based on the direction they are 'spinning'. There is an Up spin and a Down spin. Up and Down spins are always paired together and Up-Up or Down-Down combinations are not allowed. No two electrons can ever be in the same place at the same time.

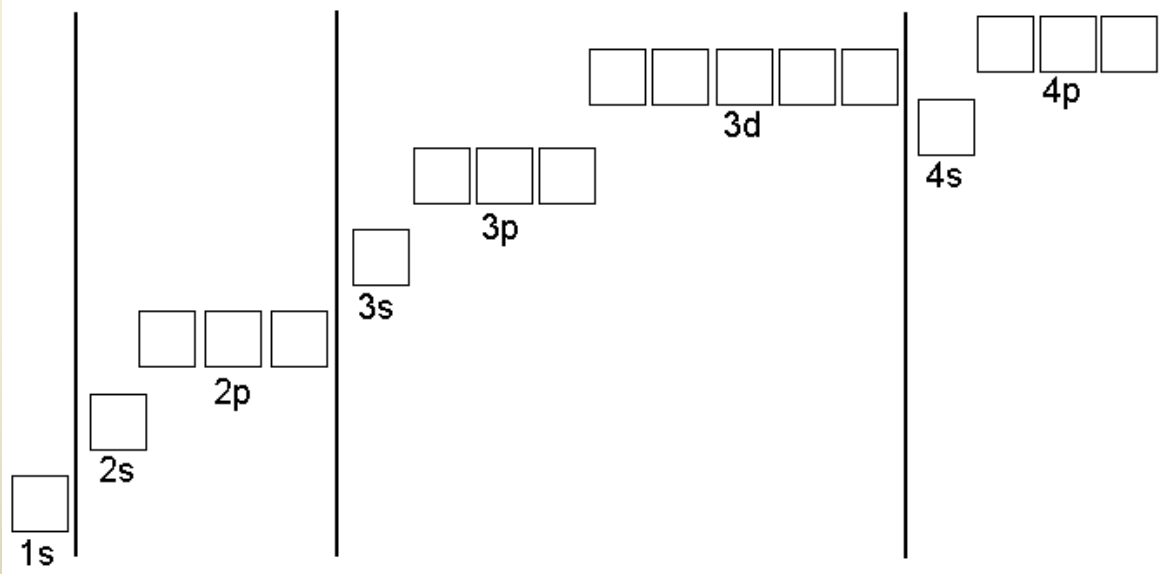
The Periodic Table – A Cheat Sheet for Knowing the Order of Filling Electron Orbitals





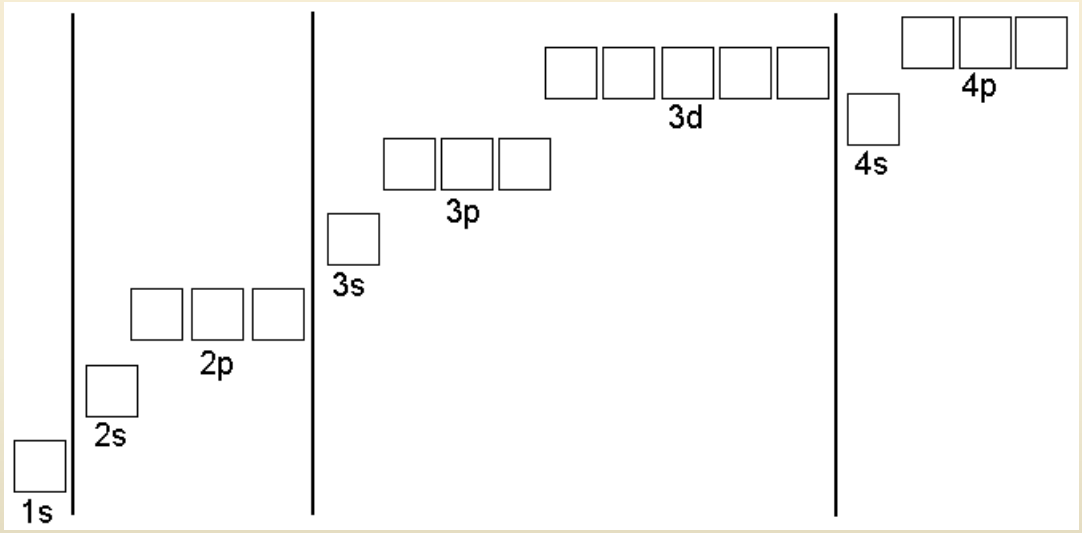
Practice!

- Fill in the electron orbitals corresponding to **He**, then write out the complete electron configuration.



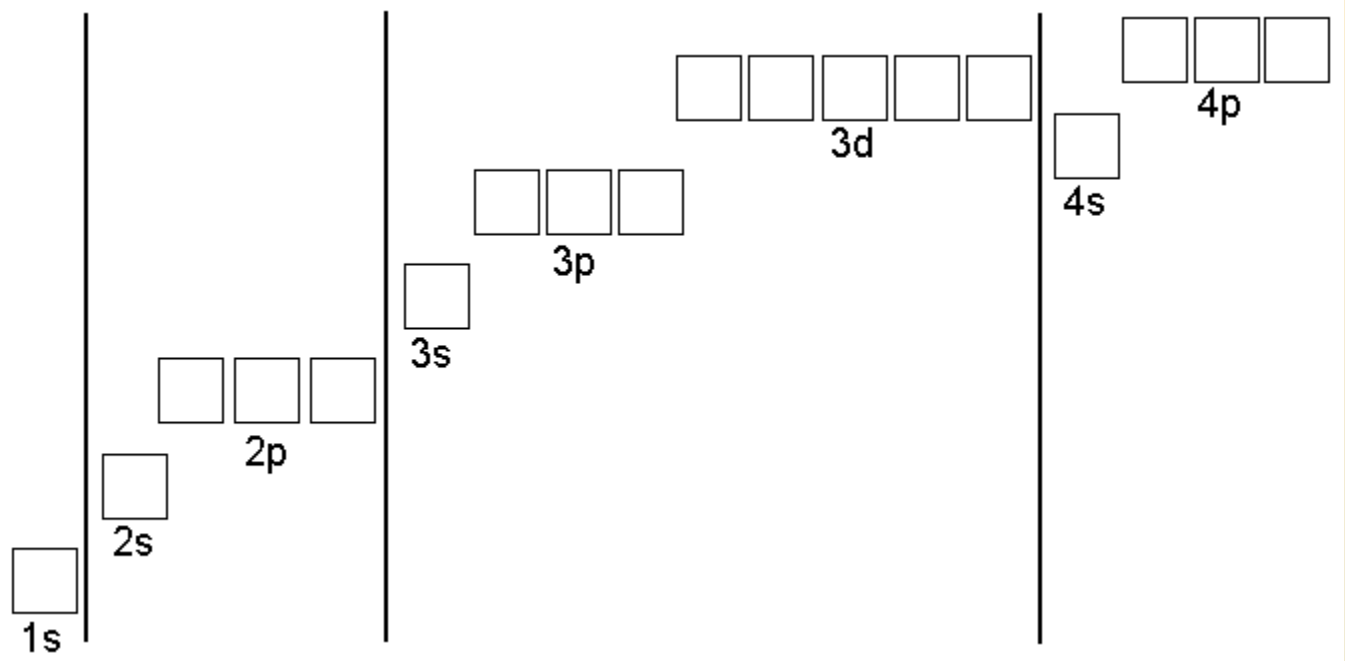
More Practice

- Fill in the electron orbitals for Si, then write out the complete electron configuration.



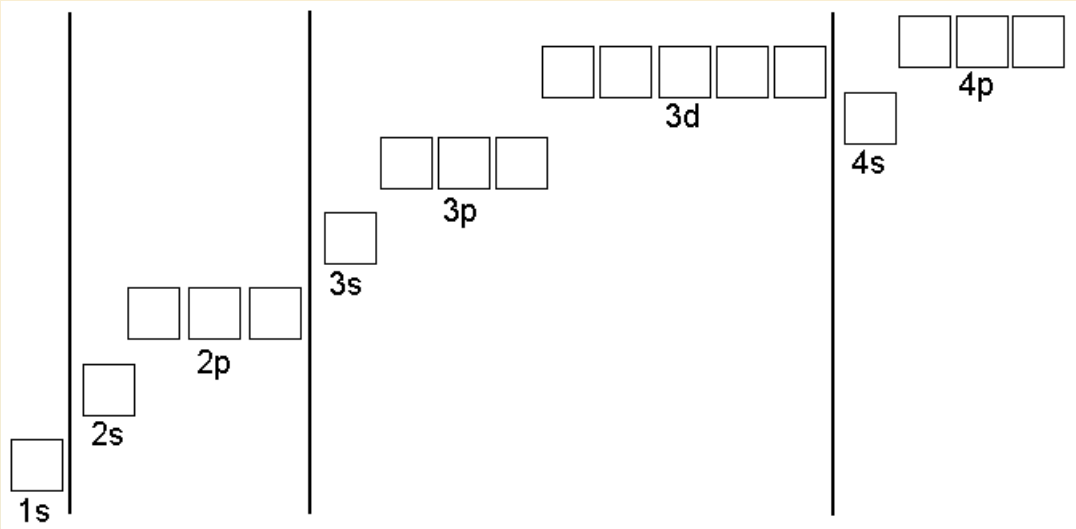
$1s^2 2s^2 2p^6 3s^2 3p^2$

Electron Configs with Elements in the d Block



Notice that when you get to the 3d orbital, it is higher in energy than the 4s orbital. The rule is that electrons fill lower energy orbitals first, so electrons will actually fill the 4s orbital after 3p, then electrons will begin to fill the 3d orbital.

Practice with the d Block



- Write the electron configuration for Titanium (Ti).

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

Noble Gas Notation

- This is much shorter and more convenient than writing out the entire electron configuration.
- Use the symbol for the noble gas that is just before the element you are configuring. (The noble gas and the element will have the same configuration, or inner electron structure, **up to that point**)
- Then complete the configuration that comes after the noble gas for the element in question.
- Example: The complete configuration for Na is $1s^2 2s^2 2p^6 3s^1$. Neon is the noble gas that comes before Na on the periodic table. So the noble gas notation for Na would be: $[Ne]3s^1$

Practice!

- Write the noble gas notation for the following elements:
  - Chlorine $[Ne]3s^2 3p^5$
  - Beryllium $[He]2s^2$

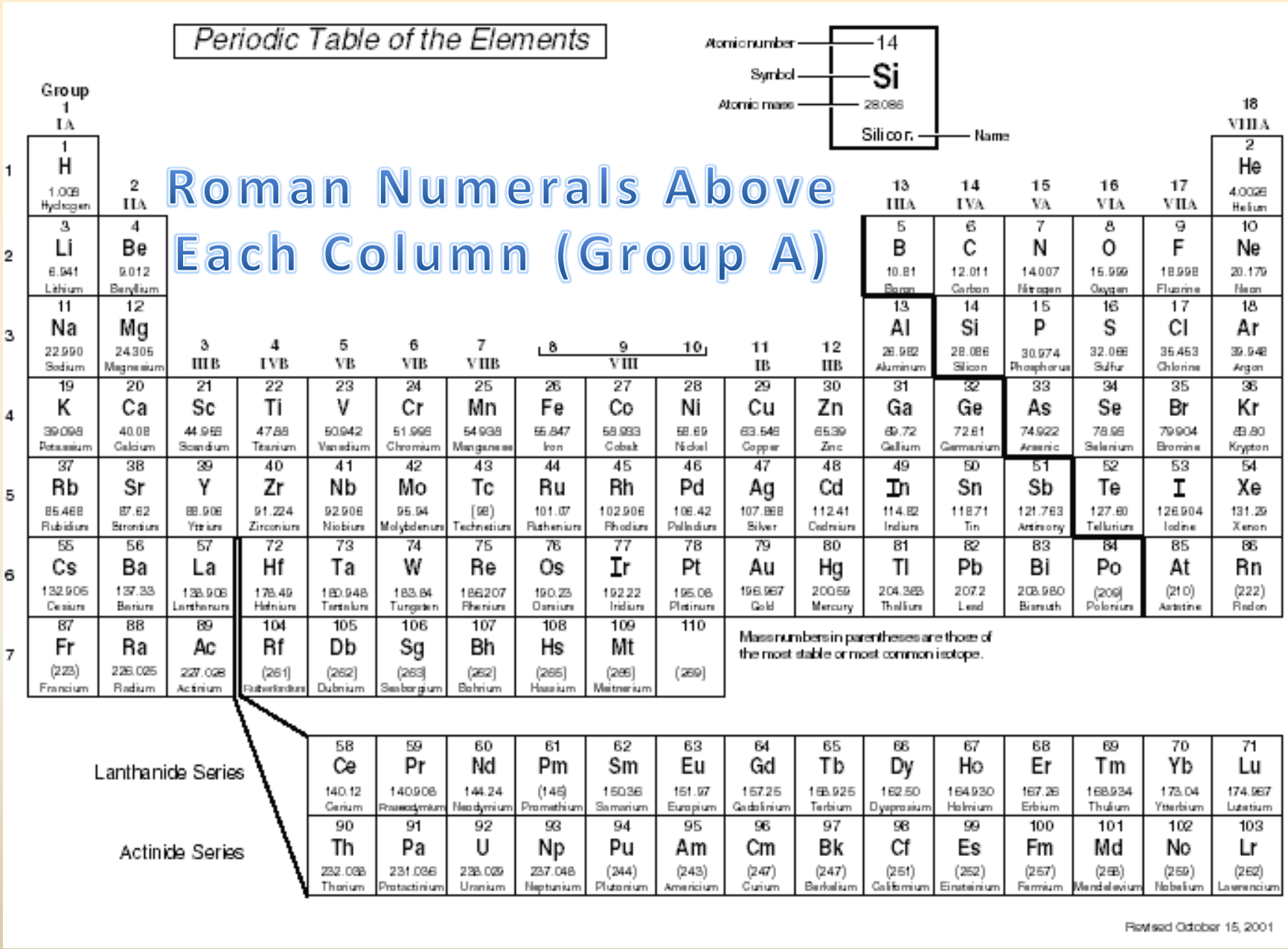
More Practice

- Which element has the following configuration: $[Xe]6s^{2?}$

Barium

Electron Configurations and Valence Electrons

- The outermost shell of electrons in an atom is the valence shell and it contains the valence electrons.
- The outermost shell contains the electrons that can interact most with the rest of the world.
- A full valence shell contains 8 electrons (2 from an s orbital and 6 from a p orbital), unless you're hydrogen or helium (only want 2 to fill their outermost s shell to become stable).


Periodic Table of the Elements
Atomic number
Symbol
Atomic mass
Name
14
Si
28.086
Silicon
Roman Numerals Above Each Column (Group A)
Group 1 IA
2 IIA
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8 9 10 VIII
11 IB
12 IIB
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
18 VIIIA
1 H 1.008 Hydrogen
2 He 4.0026 Helium
3 Li 6.941 Lithium
4 Be 9.012 Beryllium
5 B 10.81 Boron
6 C 12.011 Carbon
7 N 14.007 Nitrogen
8 O 15.999 Oxygen
9 F 18.998 Fluorine
10 Ne 20.179 Neon
11 Na 22.990 Sodium
12 Mg 24.305 Magnesium
13 Al 26.982 Aluminum
14 Si 28.086 Silicon
15 P 30.974 Phosphorus
16 S 32.066 Sulfur
17 Cl 35.453 Chlorine
18 Ar 39.948 Argon
19 K 39.098 Potassium
20 Ca 40.08 Calcium
21 Sc 44.956 Scandium
22 Ti 47.88 Titanium
23 V 50.942 Vanadium
24 Cr 51.996 Chromium
25 Mn 54.938 Manganese
26 Fe 55.847 Iron
27 Co 58.933 Cobalt
28 Ni 58.69 Nickel
29 Cu 63.546 Copper
30 Zn 65.39 Zinc
31 Ga 69.72 Gallium
32 Ge 72.61 Germanium
33 As 74.922 Arsenic
34 Se 78.96 Selenium
35 Br 79.904 Bromine
36 Kr 83.80 Krypton
37 Rb 85.468 Rubidium
38 Sr 87.62 Strontium
39 Y 88.906 Yttrium
40 Zr 91.224 Zirconium
41 Nb 92.906 Niobium
42 Mo 95.94 Molybdenum
43 Tc (98) Technetium
44 Ru 101.07 Ruthenium
45 Rh 102.906 Rhodium
46 Pd 106.42 Palladium
47 Ag 107.868 Silver
48 Cd 112.41 Cadmium
49 In 114.82 Indium
50 Sn 118.71 Tin
51 Sb 121.763 Antimony
52 Te 127.60 Tellurium
53 I 126.904 Iodine
54 Xe 131.29 Xenon
55 Cs 132.905 Cesium
56 Ba 137.33 Barium
57 La 138.906 Lanthanum
72 Hf 178.49 Hafnium
73 Ta 180.948 Tantalum
74 W 183.84 Tungsten
75 Re 186.207 Rhenium
76 Os 190.23 Osmium
77 Ir 192.22 Iridium
78 Pt 195.08 Platinum
79 Au 196.967 Gold
80 Hg 200.59 Mercury
81 Tl 204.383 Thallium
82 Pb 207.2 Lead
83 Bi 208.980 Bismuth
84 Po (209) Polonium
85 At (210) Astatine
86 Rn (222) Radon
87 Fr (223) Francium
88 Ra 226.025 Radium
89 Ac 227.028 Actinium
104 Rf (261) Rutherfordium
105 Db (262) Dubnium
106 Sg (263) Seaborgium
107 Bh (262) Bohrium
108 Hs (265) Hassium
109 Mt (266) Meitnerium
110 (269)
Mass numbers in parentheses are those of the most stable or most common isotope.
Lanthanide Series
58 Ce 140.12 Cerium
59 Pr 140.908 Praseodymium
60 Nd 144.24 Neodymium
61 Pm (145) Promethium
62 Sm 150.36 Samarium
63 Eu 151.97 Europium
64 Gd 157.25 Gadolinium
65 Tb 158.925 Terbium
66 Dy 162.50 Dysprosium
67 Ho 164.930 Holmium
68 Er 167.26 Erbium
69 Tm 168.934 Thulium
70 Yb 173.04 Ytterbium
71 Lu 174.967 Lutetium
Actinide Series
90 Th 232.038 Thorium
91 Pa 231.036 Protactinium
92 U 238.029 Uranium
93 Np 237.048 Neptunium
94 Pu (244) Plutonium
95 Am (243) Americium
96 Cm (247) Curium
97 Bk (247) Berkelium
98 Cf (251) Californium
99 Es (252) Einsteinium
100 Fm (257) Fermium
101 Md (258) Mendelevium
102 No (259) Nobelium
103 Lr (262) Lawrencium
Revised October 15, 2001

How many valence electrons in….

- **Oxygen -** $1s^2$ **$2s^2$ $2p^4$**

- **Sulfur -** $1s^2$ $2s^2$ $2p^6$ **$3s^2$ $3p^4$**

The outermost shell contains the valence electrons, so find the highest number in the electron configuration and count the number of electrons in it.