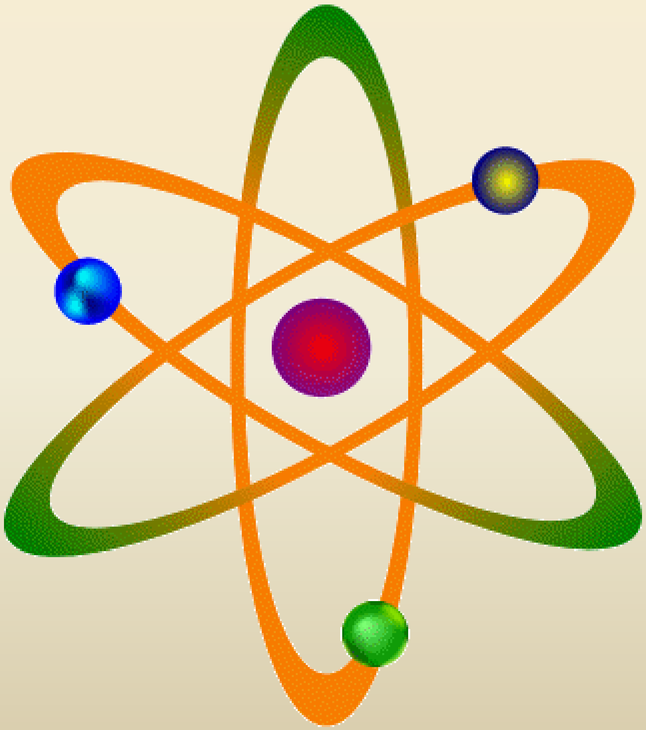
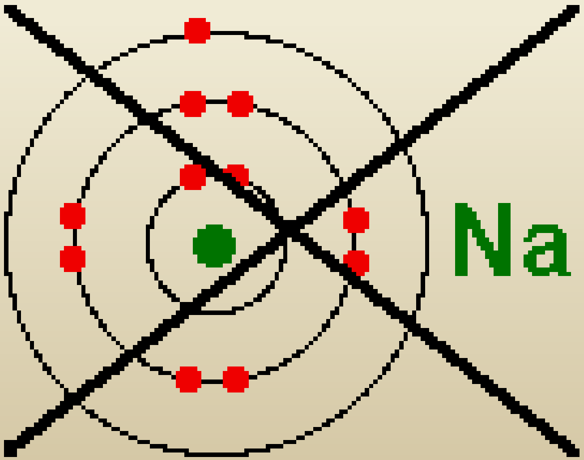
Electron Configurations



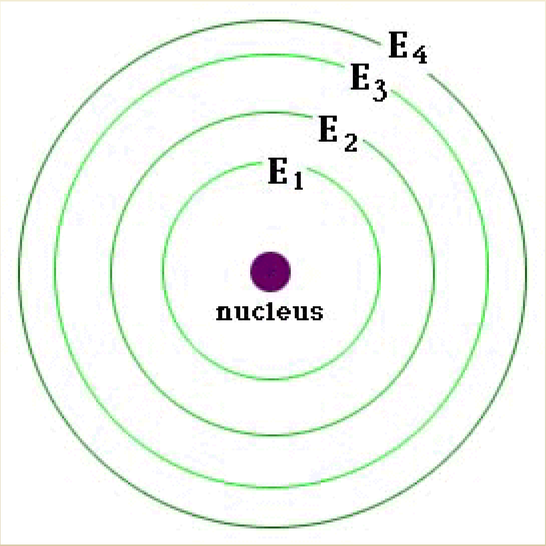
Electron Arrangement in an Atom

- 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.



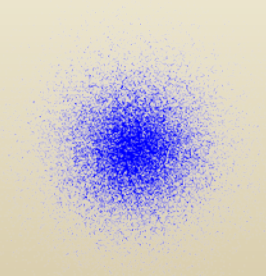
Energy Levels

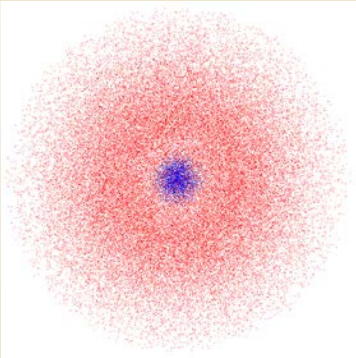
- There are "shells" or energy levels around an atom. The farther away an energy level is from the nucleus, the more energy the sublevel has.



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

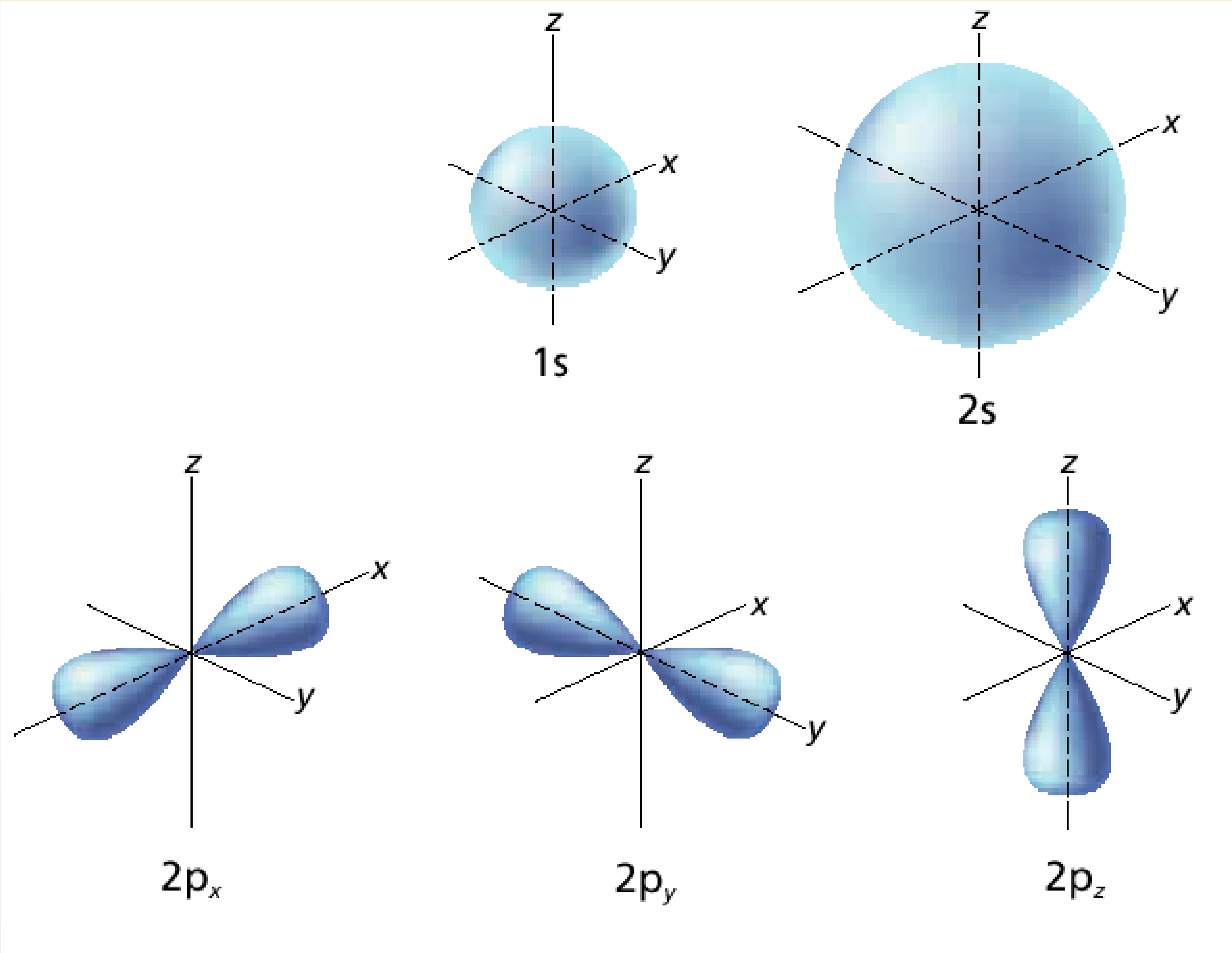
Orbitals, con'td

- 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)

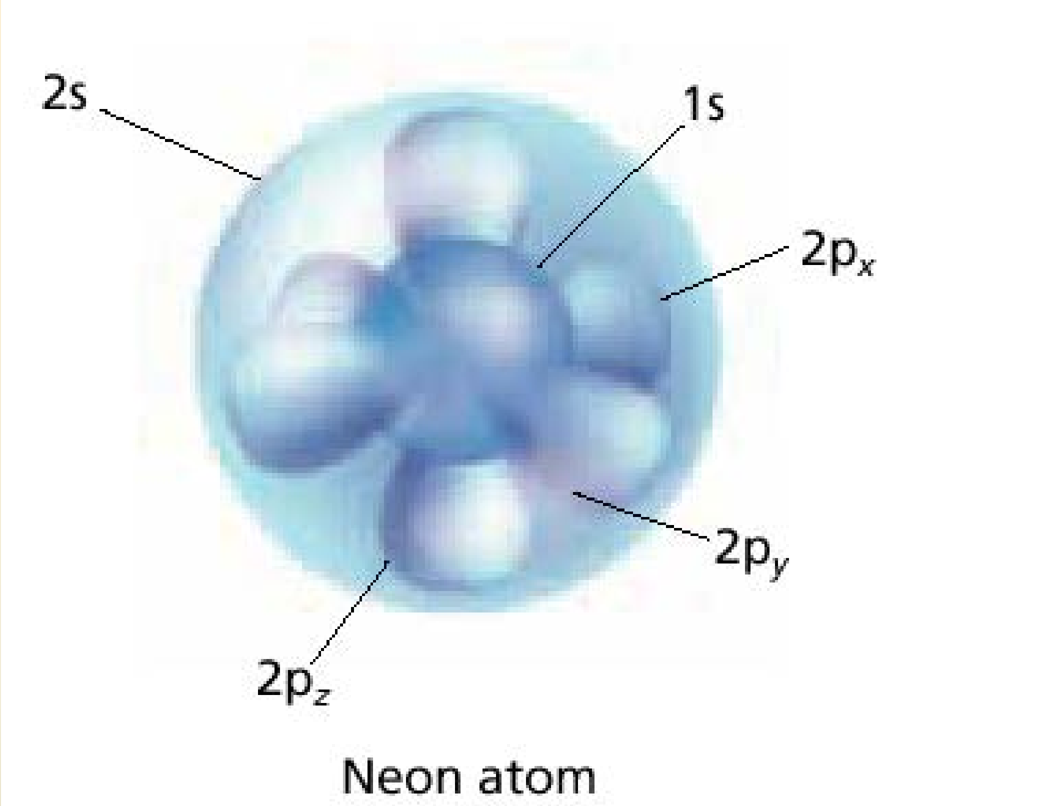
If a vehicle were an orbital…..

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

So how do the orbitals REALLY look?

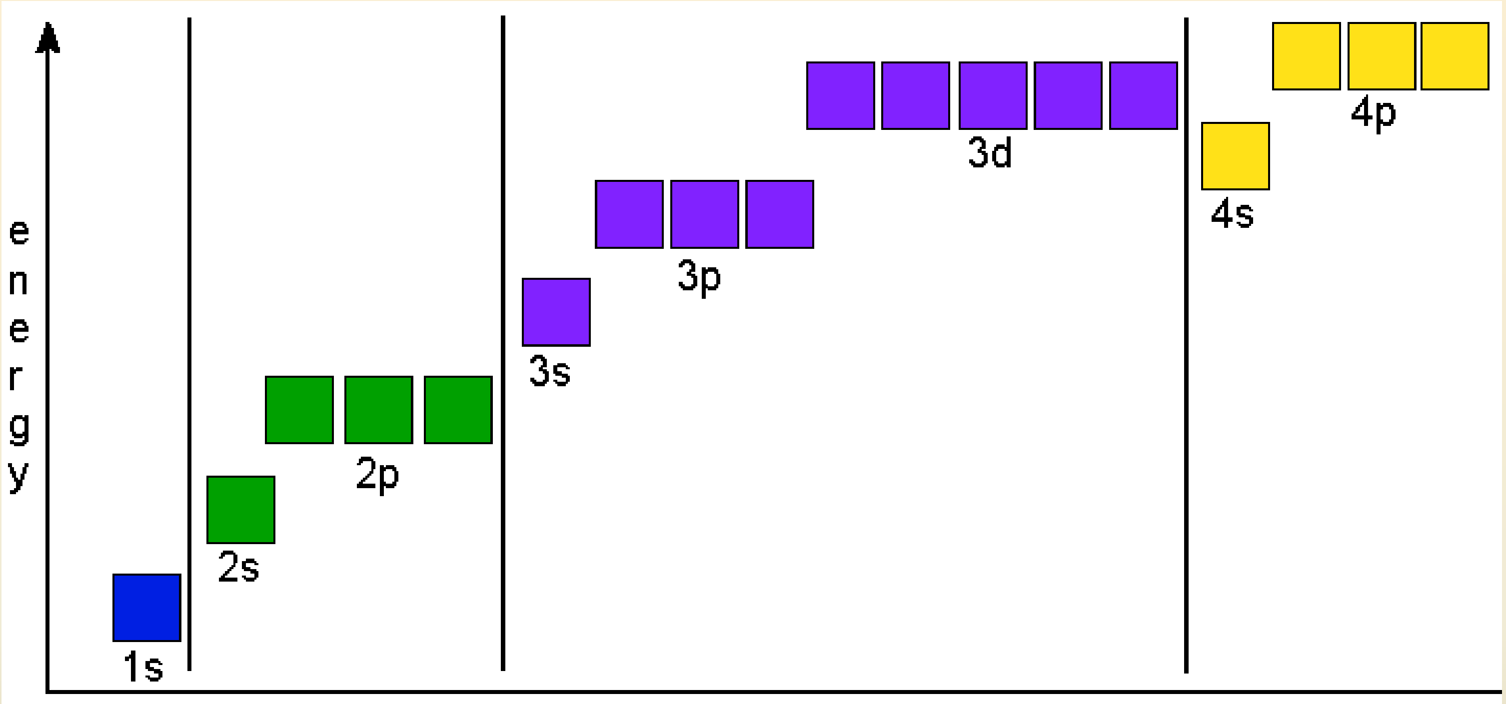


Putting the s and p orbitals together…..



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….



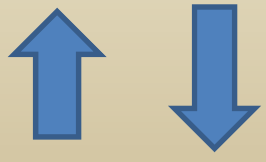
- The boxes represent the different orbitals. As the number of the level increases, the energy increases. Each individual box can hold 2 electrons at a time.

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?

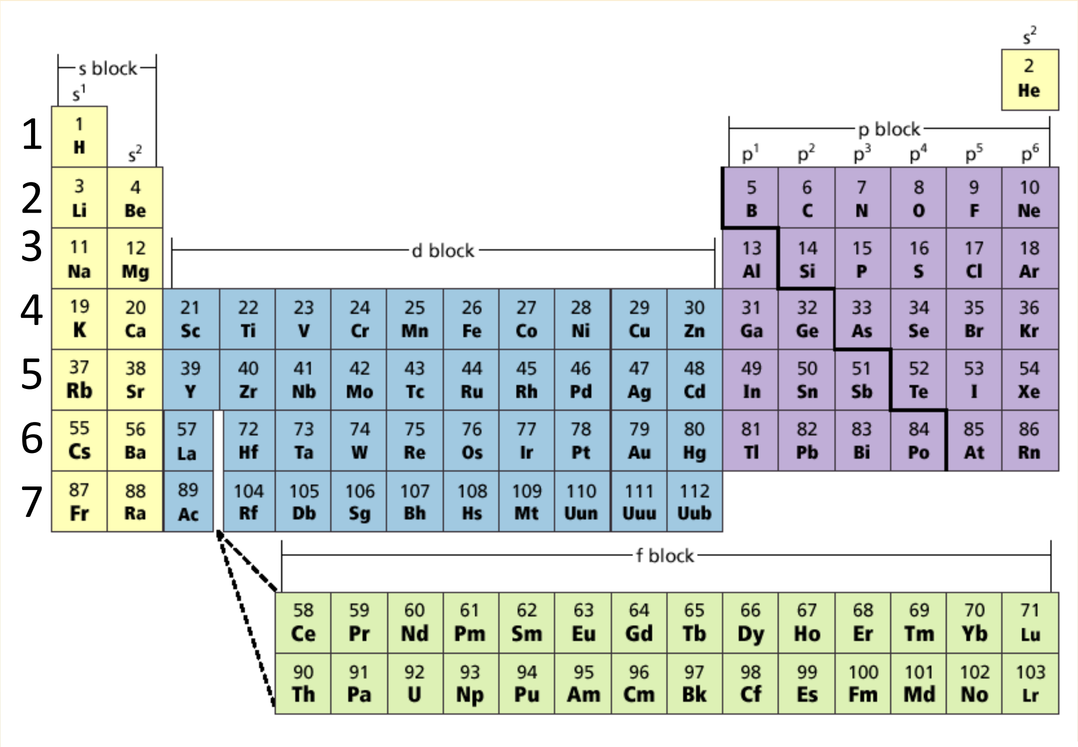
- Different floors in the apartment represent different energy levels or shells.
- Each room on each floor of the apartment house corresponds to an orbital, or one box from the previous diagram.
- Each room on each floor can hold up to 2 people (the electrons), and each room is filled with one person 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)

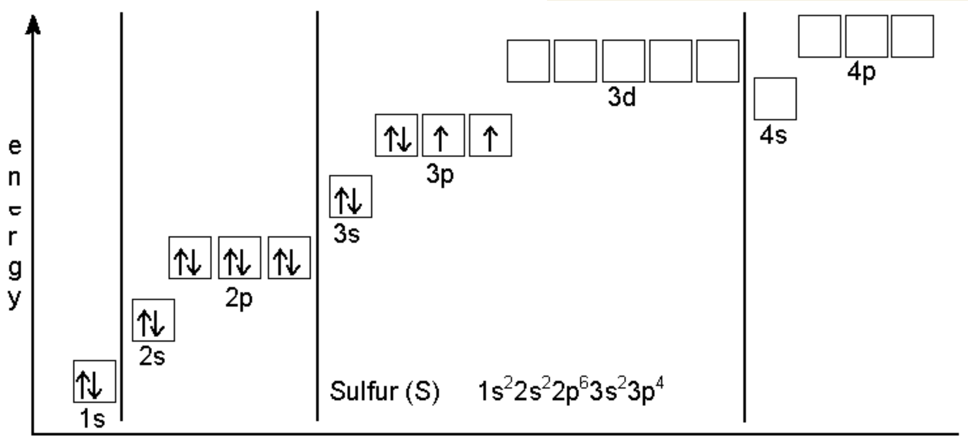


Who figured this out and how does it relate to the apartment analogy?!?

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.

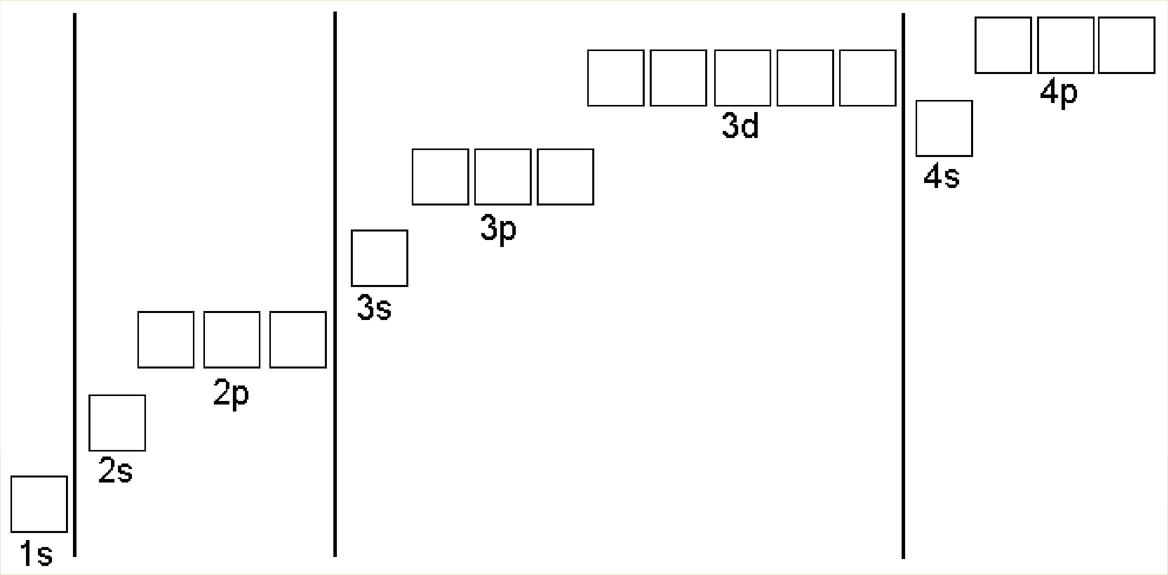
The Periodic Table – A Cheat Sheet for Knowing the Order of Filling Electron Orbitals





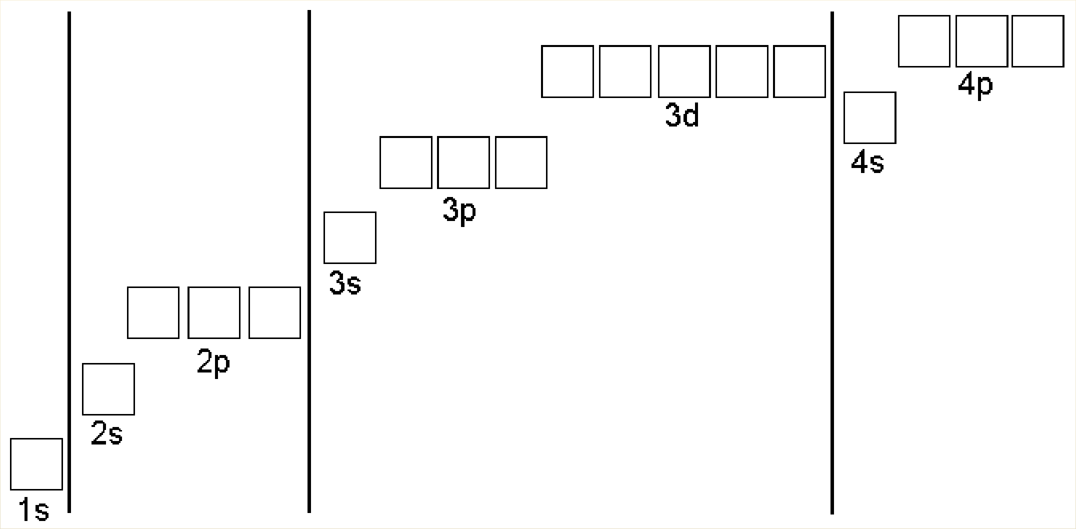
Practice!

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



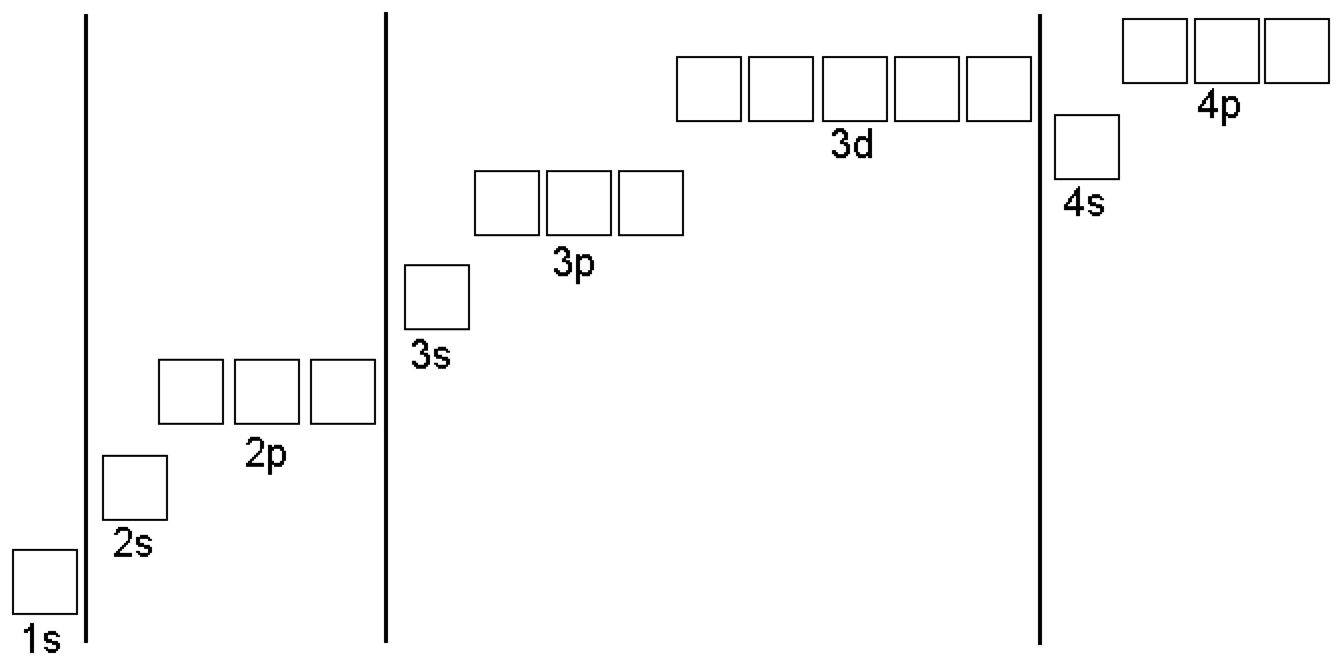
More Practice

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



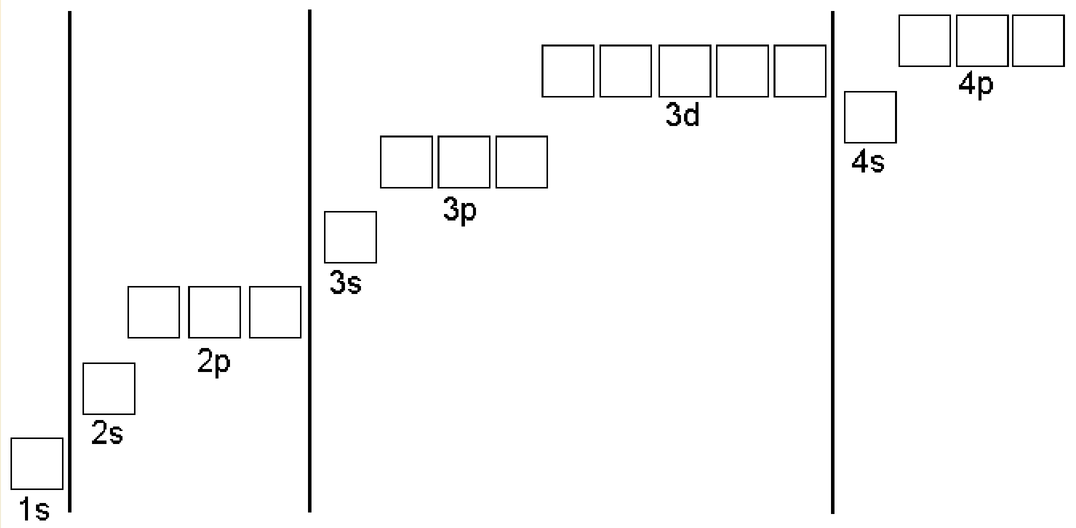
$1s^2 2s^2 2p^6 3s^2 3p^2$

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 — 14
Symbol — Si
Atomic mass — 28.086
Name — Silicon

Roman Numerals Above Each Column (Group A)

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008 Hydrogen																	2 He 4.0026 Helium
2	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
3	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
4	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
5	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
6	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
7	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.

Series														
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.

Valence Electrons and Lewis Dot Structures

- Remember valence electrons determine the chemical properties of an element because they are the outermost electrons that interact with the outside world.
- We can use Lewis dot structures to help represent these important valence electrons for each element.

Electron-Dot Structures for Elements in Period Two

Element	Atomic number	Electron configuration	Electron-dot structure
Lithium	3	$1s^2 2s^1$	Li·
Beryllium	4	$1s^2 2s^2$	·Be·
Boron	5	$1s^2 2s^2 2p^1$	·Ḃ·
Carbon	6	$1s^2 2s^2 2p^2$	·Ċ·
Nitrogen	7	$1s^2 2s^2 2p^3$	·N̈·
Oxygen	8	$1s^2 2s^2 2p^4$	:Ö·
Fluorine	9	$1s^2 2s^2 2p^5$	:F̈·
Neon	10	$1s^2 2s^2 2p^6$	:N̈e:

Practice!

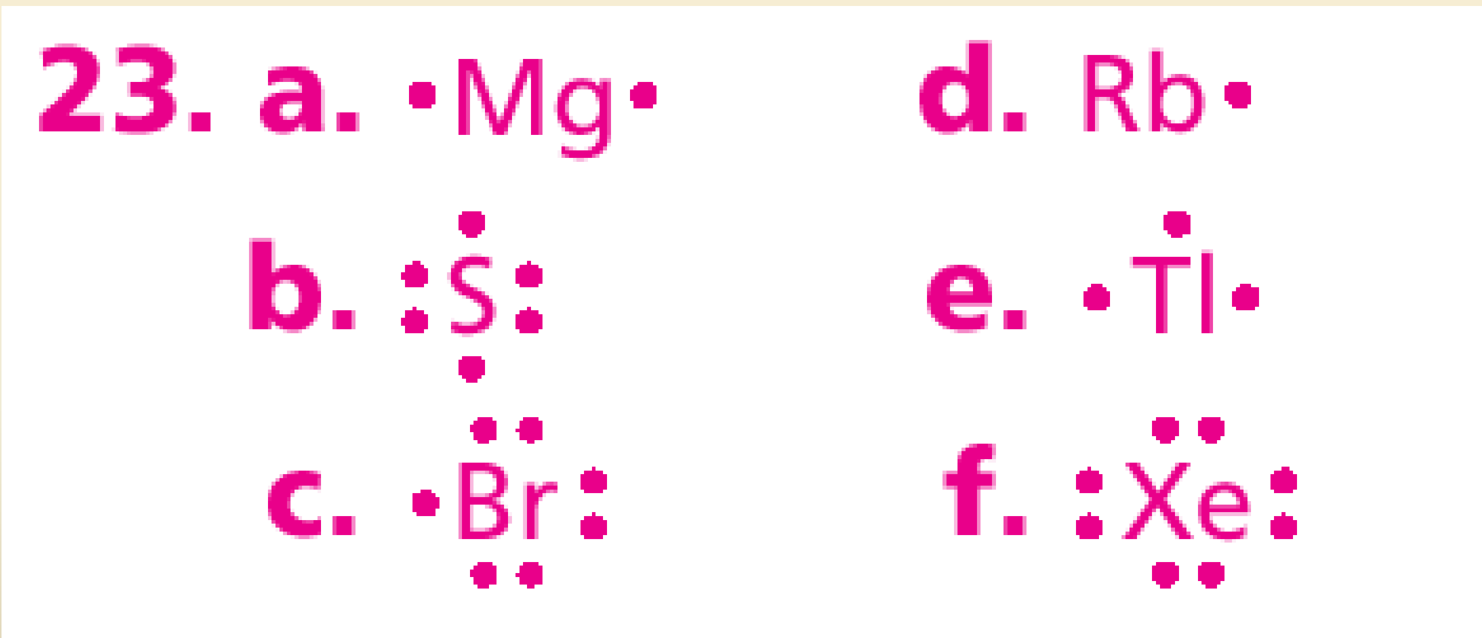
- Step 1: Use the periodic table to determine the number of valence electrons in an atom of a certain element.
- Step 2: Write the element symbol and place the dots (valence electrons) on each of the four sides of the symbol; singles first and then pair them if necessary.

PRACTICE PROBLEMS

23. Draw electron-dot structures for atoms of the following elements.

a. magnesium
b. sulfur
c. bromine
d. rubidium
e. thallium
f. xenon

Check Your Work



Ions and Electron Configuration

- Remember that CATIONS are positively charged atoms and ANIONS are negatively charged atoms.
- These form because of the need for an atom to achieve stability that the noble gases have.
- Understanding electron arrangement in an atom, especially the electrons in the outermost shell (valence), can help you determine why the elements form the ions that they do.
  - PRE-AP ONLY