Atomic Structure and the Periodic Table

Chapter 3.5

The Periodic Table

- The elements of the periodic table are arranged according to the way electrons arrange themselves around the nuclei of atoms
- Electron arrangement determines the chemical behavoiur of every element

Periodic Table

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 23.00	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Ha (262)	106 Unh (263)	107 Uns (262)		109 Une (267)									

Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

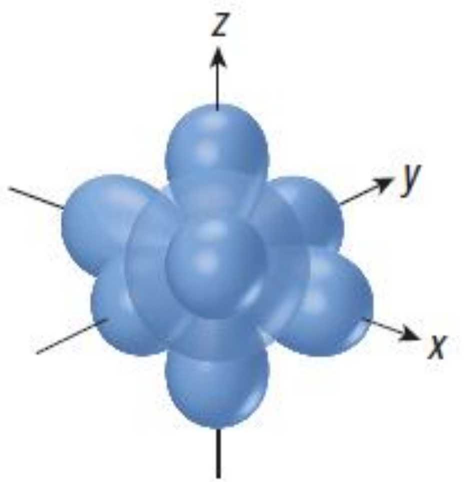
The Quantum Mechanical Model of the Atom, with its four quantum numbers

- Describes all atoms in the periodic table
- Allows us to make predictions about atoms and their chemical properties

Multi-electronic Atoms

- Three energy contributions must be considered in the description of a multi-electron atom

1. The kinetic energy of the electrons as they move about the nucleus
2. The potential energy of the attraction between the nucleus and electrons
3. The potential energy of repulsion between the two electrons

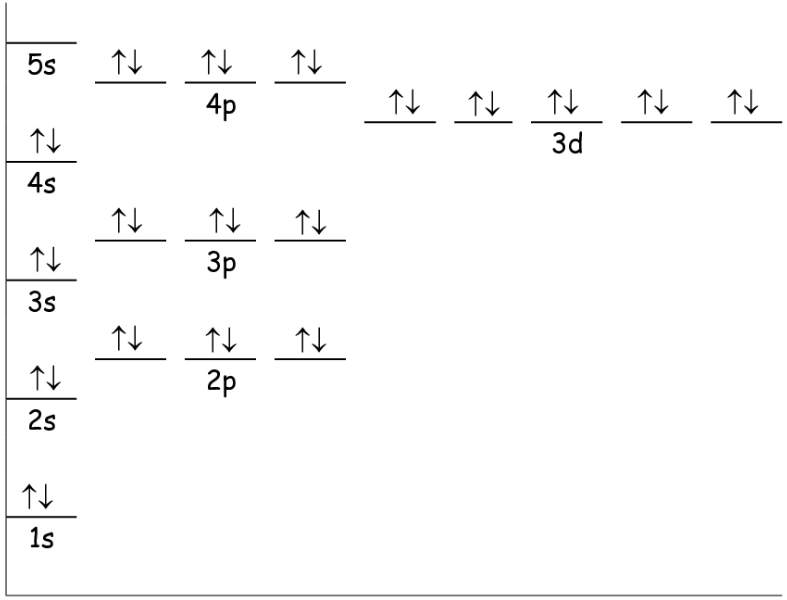


Usually, #2 and #3 are grouped together as the **net** effect on the electron is what matters

Most outer electrons are screened or shielded from the nuclear charge by the repulsions of other electrons

Drawing Energy Level Diagrams

- An **energy level diagram**, or orbital diagram, is a diagram that represents the relative energies of electrons in the atom



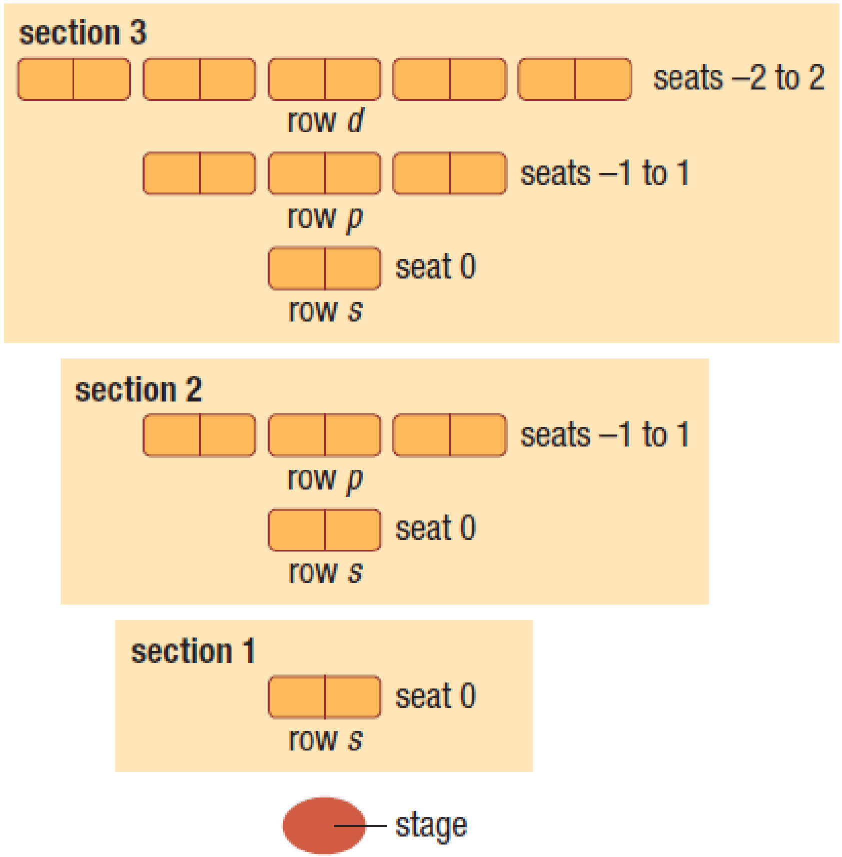
- Three main rules must be followed when drawing energy level diagrams:

1. Pauli Exclusion Principle
2. Aufbau Principle
3. Hund's Rule

Aufbau Principle

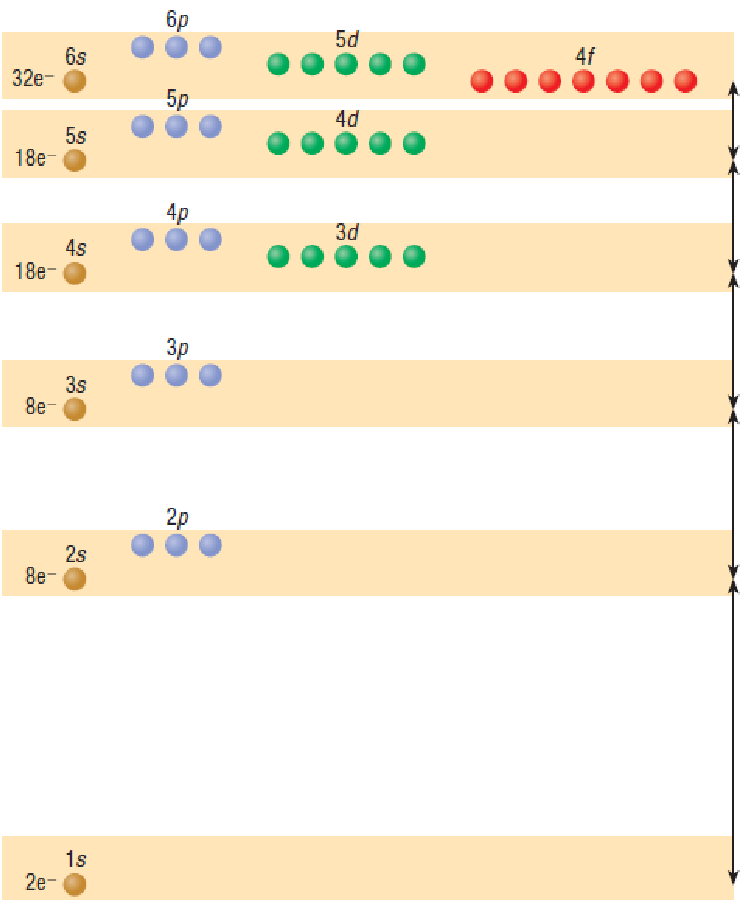
- The word *aufbau* is German for ‘building up’
- The principle says that an atom is ‘built up’ by progressively adding electrons, and that electrons fill the lowest available energy sublevels before filling higher energy sublevels

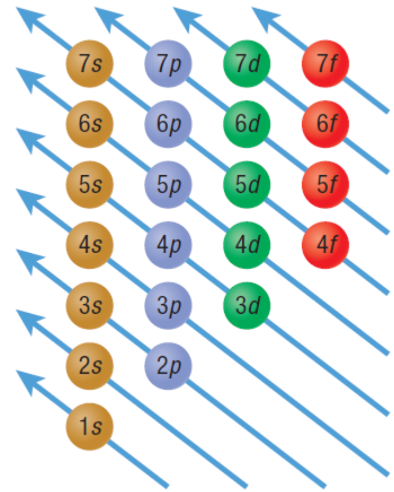
I like to call this one
the “Concert Hall Principle”



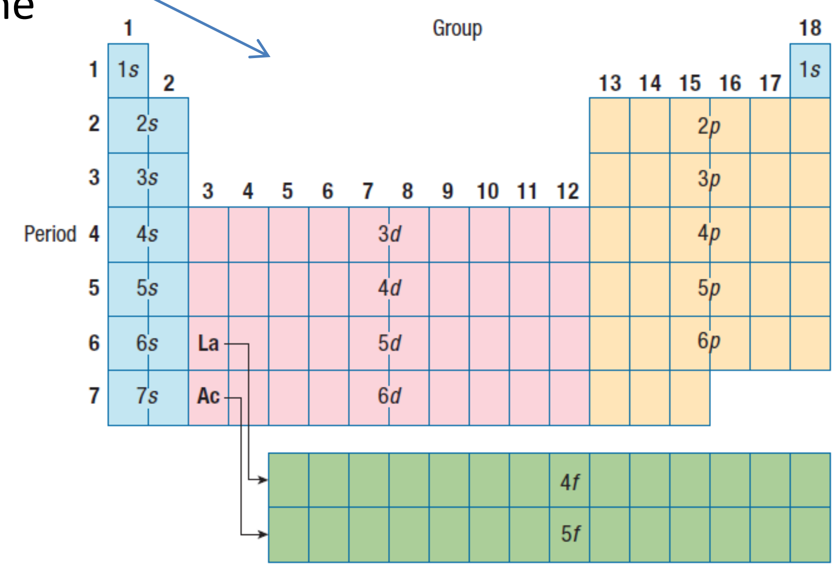
Aufbau Principle

- There are a few diagrams that you can use to help you with the order of the subshells





This one makes the most sense to me



Hund's Rule

- Hund's rule states that in orbitals within the same sublevel (having the same energy), the lowest energy configuration for an atom is the one with the maximum number of unpaired electrons
- This means that before any two electrons occupy an orbital in a subshell, other orbitals within the same subshell must first each contain one electron
- These unpaired electrons will have parallel spins

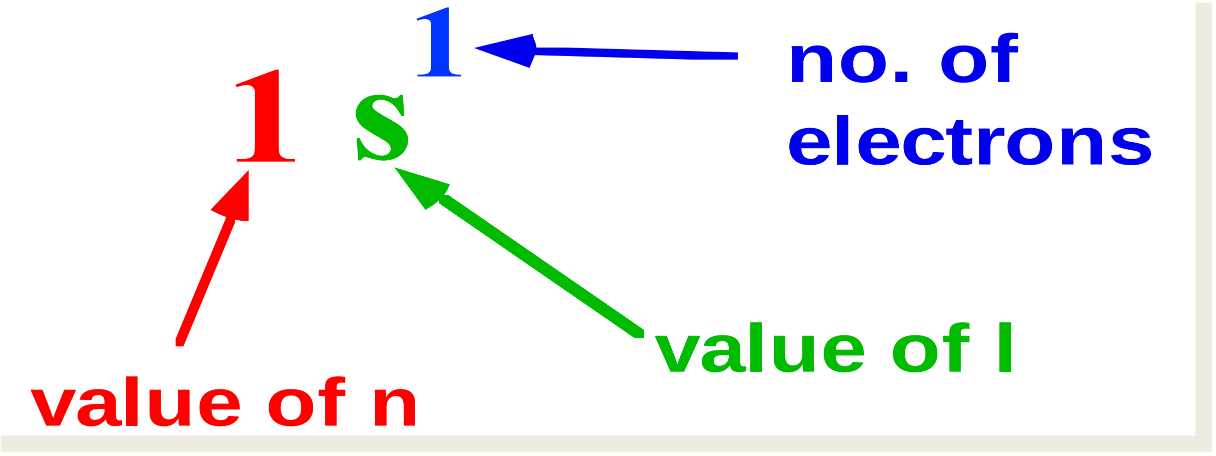
I like to call this one the "Bus Rule"

Practice

- Draw the energy level diagram for tellurium

Electron Configuration

- **Electron Configuration** is a description of the location and number of electrons in the electron energy levels of an atom



- Practice: Write the electron configuration for tellurium

Ways of Expressing Electron Configurations

- Full configuration
  - Complete ordered placement starting with $1s^2$
    - $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$
    - $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$
- Condensed configuration
  - Completed noble gas configuration in brackets followed by detail for unfilled valence shell
    - [Ar] $4s^2\ 3d^4$
    - [Ar] $4s^2\ 3d^{10}\ 4p^2$
- Orbital diagrams for outer valence shell
  - Labeled picture of outer valence shell

Summary

Procedure for Writing an Electron Configuration

1. Use the periodic table to determine the number of electrons in the atom or ion.
2. Assign electrons by main energy level and then by sublevel, using an energy-level diagram or an aufbau diagram.
3. Distribute electrons into orbitals that have the same energy according to Hund's rule.
4. Fill each sublevel before starting with the next sublevel. Continue until all electrons are assigned.
   - For anions (negatively charged ions), add an appropriate number of additional electrons.
   - For cations (positively charged ions), remove an appropriate number of electrons.

Explaining the Periodic Table

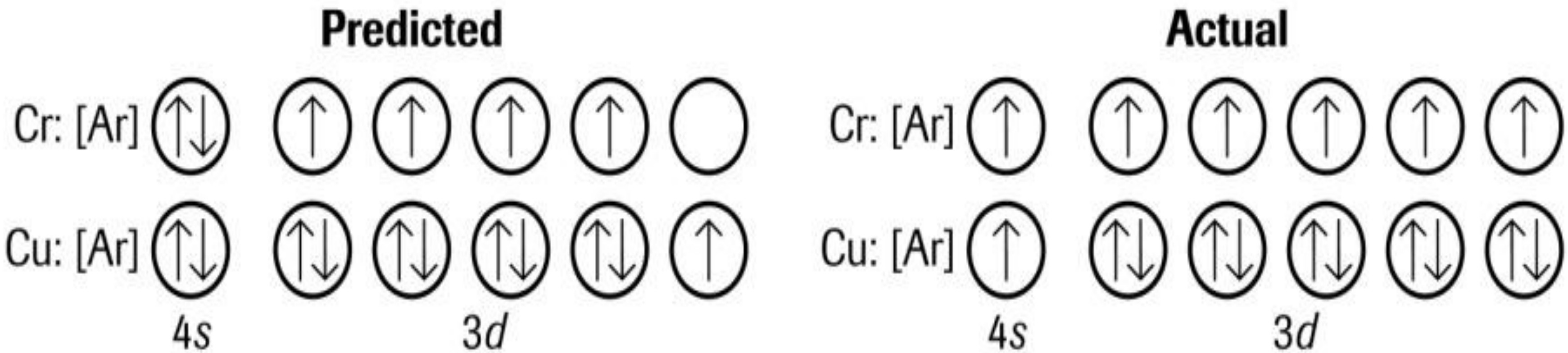
- **Valence electrons** are the electrons in the outermost shell (outermost principal quantum level) of an atom
- The elements in the same group on the periodic table have the same valence electron configuration
- Elements with the same valence electron configuration show similar chemical behaviour
- Electron configurations can be used to explain periodic trends

  For example:

  Why is the atomic radius of potassium larger than that of sodium?

  Why is the first ionization energy higher in beryllium than in lithium?

Exceptions to Aufbau's Principle



Explaining Ion Charges

- Why does cadmium form a +2 ion?

- Why does lead form both a +2 and +4 ion?

Explaining Magnetism

- **Ferromagnetism** is the very strong magnetism commonly exhibited by commonly exhibited by materials that contain nickel, iron, and cobalt

Table 1 Electron Configurations of Ferromagnetic Elements

Ferromagnetic element	Electron configuration	*d*-orbital filling	Pairing of *d* electrons
Fe	$[Ar]4s^23d^6$	↑↓ ↑ ↑ ↑ ↑	1 pair; 4 unpaired
Co	$[Ar]4s^23d^7$	↑↓ ↑↓ ↑ ↑ ↑	2 pairs; 3 unpaired
Ni	$[Ar]4s^23d^8$	↑↓ ↑↓ ↑↓ ↑ ↑	3 pairs; 2 unpaired

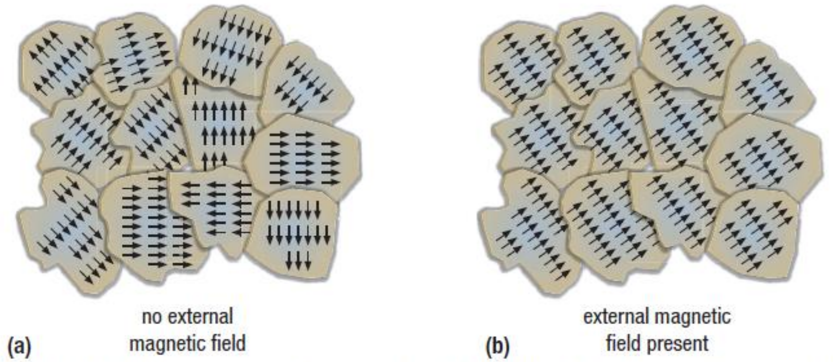


Figure 11 (a) In the absence of an external magnetic field, the magnetic domains are randomly aligned. (b) In the presence of a magnetic field, the domains align with the field. Once aligned, these domains stay aligned until they are disturbed.

- **Paramagnetism** is the weak attraction of a substance to a magnet
- A magnetic field is generated when unpaired electrons in an atom are spinning in the same direction

HOMEWORK

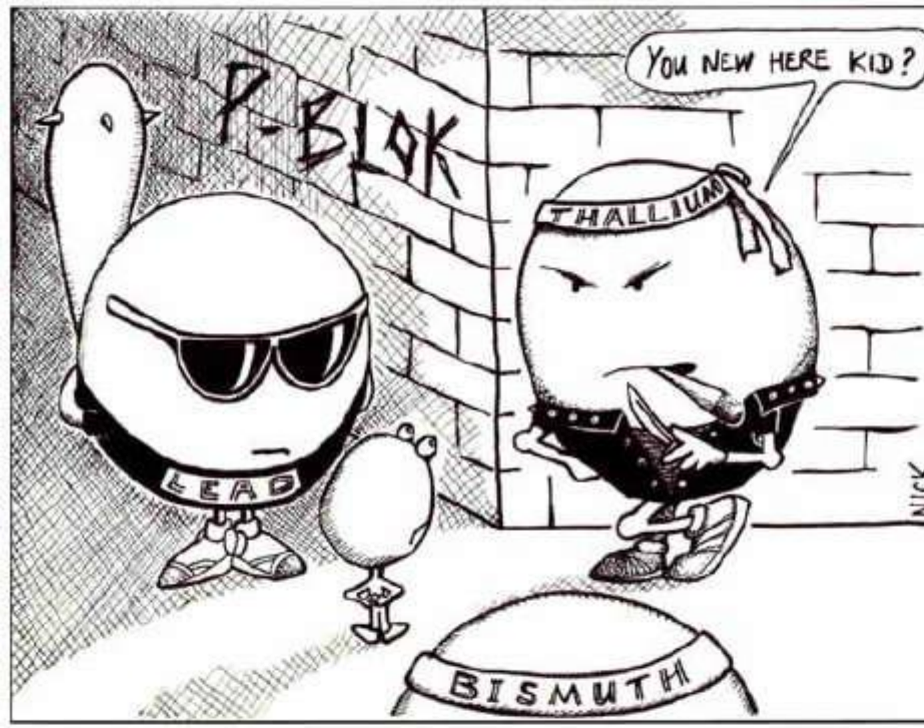
Required Reading:

p. 160-172

(remember to supplement your notes!)

Questions:

p. 172 #1-10



Unwittingly, and against his mother's advice, Vince the first-row Transition Metal had been lured far away from home, and now found himself surrounded by heavier elements of the P-Block.