Chapter 8: Periodic properties of the elements

Electron configuration: shows which orbitals are occupied in an atom, and how many electrons they contain

Ground state: lowest energy, most stable state for an atom - has all electrons in the lowest energy possible orbitals

The energy of an electron in an H atom depends only on the principal quantum number, n, so in its ground state, the electron in an H atom occupies a ___ orbital.

Electron configuration:

Orbital diagram: figure that organizes electrons into their orbitals. Orbital = box, electron = arrow in box

H: ☐

Electron spin: direction of an electron's inherent angular momentum - this creates a magnetic field around the electron that either points **up** or **down**.

Spin quantum number, m_s, defines electron spin

- $m_s = +\frac{1}{2}$: up spin
- $m_s = -\frac{1}{2}$: down spin

Multi-electron atoms

The first 3 quantum numbers define an orbital

All 4 quantum numbers define **one electron** in an atom

- ***n*:** size of orbital
- ***ℓ*:** shape of orbital
- **m_ℓ:** orientation of orbital
- **m_s**: spin of electron in that orbital

Pauli exclusion principle: no two electrons in an atom can have the same four quantum numbers

This means each orbital can hold no more than ___ electrons

He, 2 electrons, ground state electron configuration:

Orbital diagram: ☐

Be, 4 electrons, configuration:

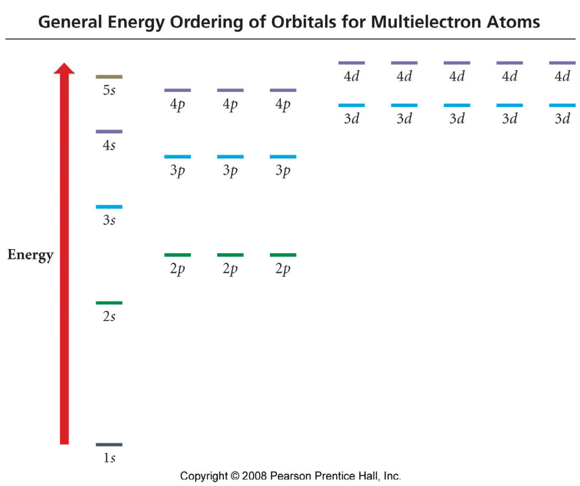
Orbital diagram:

Energy of electrons in multi-electron atoms

In hydrogen, *n* is the only quantum number necessary to calculate the energy of an orbital

In multi-electron atoms, both *n* and *ℓ* influence the energy of an orbital

Energies of *ℓ*: (lowest) **s < p < d < f** (highest)



B (5 electrons) - configuration:

Orbital diagram:

Also, since energies get closer together as *n* increases, a **4s** orbital is lower in energy than a **3d** orbital

Electron configurations

H

He

Li

Be

B

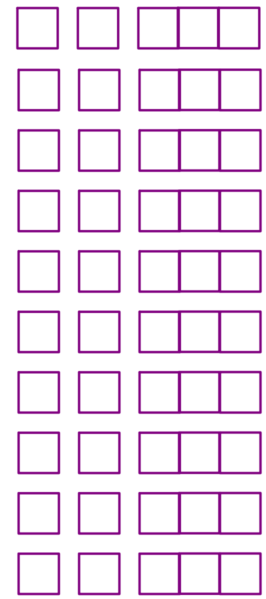
C

N

O

F

Ne



<u>Hund's rule</u>: Electrons fill orbitals with equal energy **singly** first with parallel spins.

<u>Inner electrons</u>: A full noble gas electron configuration inside an atom - represented with noble gas symbol in brackets to make **<u>abbreviated electron configuration.</u>**

Periodic table and valence electrons

Outer Electron Configurations of Elements 1–18

1A	2A	3A	4A	5A	6A	7A	8A
1 H $1s^1$							2 He $1s^2$
3 Li $2s^1$	4 Be $2s^2$	5 B $2s^22p^1$	6 C $2s^22p^2$	7 N $2s^22p^3$	8 O $2s^22p^4$	9 F $2s^22p^5$	10 Ne $2s^22p^6$
11 Na $3s^1$	12 Mg $3s^2$	13 Al $3s^23p^1$	14 Si $3s^23p^2$	15 P $3s^23p^3$	16 S $3s^23p^4$	17 Cl $3s^23p^5$	18 Ar $3s^23p^6$

Valence electrons: number of electrons in outermost principal energy level (*n*) (plus outermost d electrons for transition elements)

Core electrons: inner electrons plus filled d or f sublevels

Periodic table and filling order

The ***reason*** the periodic table has its shape is because of the orbitals occupied in those elements.

Periodic Table of the Elements

Period	1 IA	2 IIA		3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008																		2 He 4.003
2	3 Li 6.939	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
3	11 Na 22.99	12 Mg 24.31												13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	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 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62		39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 *Tc* (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57-70 *	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89-102 **	103 *Lr* (257)	104 *Rf* (261)	105 *Db* (262)	106 *Sg* (271)	107 *Bh* (272)	108 *Hs* (270)	109 *Mt* (276)	110 *Ds* (281)	111 *Rg* (280)	112 *Uub* (285)	113 *Uut* (284)	114 *Uuq* (289)	115 *Uup* (288)	116 *Uuh* (292)	117	118 *Uuo* (294)

*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 *Pm* (147)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
**	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 *Np* (237)	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)

Reference: http://www.webelements.com

Electron configurations

Ca:

Sc:

Sometimes, electron configurations are rearranged into order of increasing *n* (to group valence electrons better)

Se:

<u>Abbreviated configurations:</u>

Po:

Bh:

Electron configurations and magnetic properties

4s has lower energy than 3d, but they are still close.

Mn:

Zn:

Cr:

Cu:

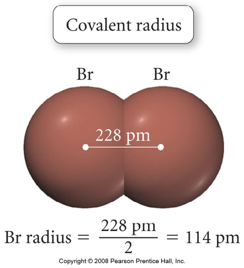
(You should be aware of the conditions behind these anomalies and be able to explain it if it occurs elsewhere, but do not memorize every exception on the periodic table!)

<u>Magnetic properties</u>

Unpaired electrons in the orbital diagram will make the element **<u>paramagnetic</u>** (weakly attracted to magnetic field)

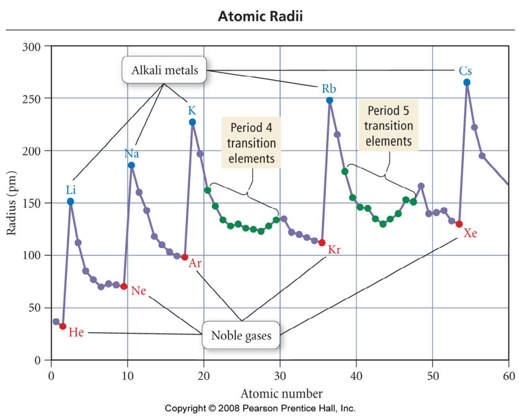
If all electrons are paired, the element is **<u>diamagnetic</u>** (not attracted by magnetic field)

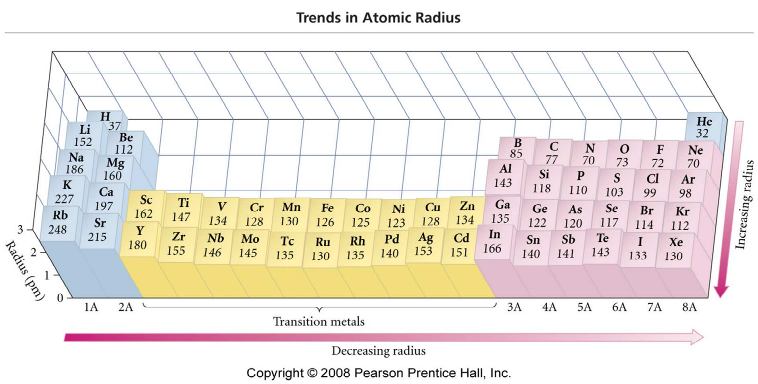
Periodic trends in atomic radius



Atomic radius **increases** going down a column:

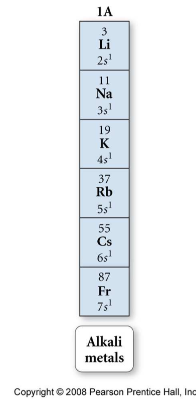
Atomic radius **decreases** going across a period (row):

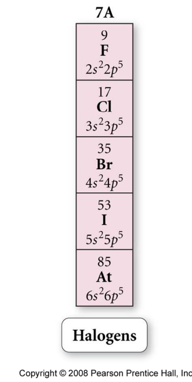




Ions

Main group ions:





Transition metal ions:

Zn: [Ar] $3d^{10}\ 4s^2$

Experimentally, the Zn^{2+} ion is diamagnetic:

Zn^{2+}:

Transition metals tend to lose the ___ electrons **before** the ___ electrons!

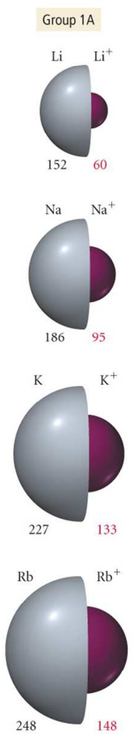
(Writing the configuration in order of increasing *n* makes ion formation easier!)

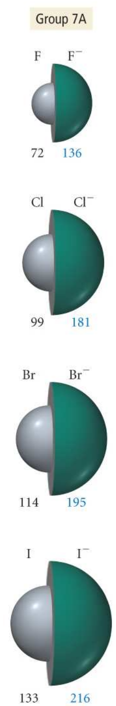
Ag^+:

Ionic radius

Na: [Ne] $3s^1$
Na^+: [Ne]

Cl: [Ne] $3s^2 3p^5$
Cl^-: [Ne] $3s^2 3p^6$





Ionization energy

Ionization energy (IE): energy required to remove 1 electron from an atom or ion

Na $\longrightarrow$ IE_1 = 496 kJ/mol

Na^+ $\longrightarrow$ IE_2 = 4560 kJ/mol

Trends in first ionization energy (IE_1):

Mg $\longrightarrow$ IE_1 = 738 kJ/mol

(additional protons across a period will increase attraction to the electrons)

K $\longrightarrow$ IE_2 = 419 kJ/mol

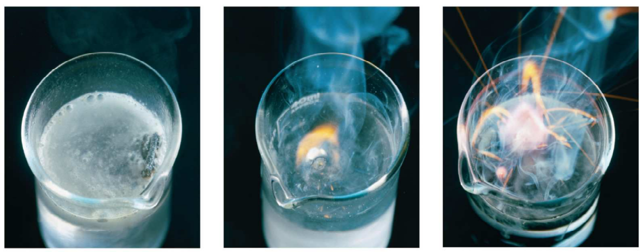
(an additional shell shields the valence electrons from the nuclear attraction)

Ionization energy and Electron affinity

$2\ Li(s) + 2\ H_2O(l) \longrightarrow 2\ LiOH(aq) + H_2(g)$

$Li \longrightarrow Li^+$
$Na \longrightarrow Na^+$
$K \longrightarrow K^+$

Reactions of the Alkali Metals with Water



Lithium Sodium Potassium

Electron affinity (EA): energy change associated with an electron being added to a neutral atom.

Li	EA = -60 kJ/mol
O	EA = -141 kJ/mol
F	EA = -328 kJ/mol