	IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIIIB 8	VIIIB 9	VIIIB 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1	1 H 1.0079																	2 He 4.0026
2	3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.4	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57-71 *	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)	89-103 #	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (270)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (291)		118 Uuo (294)

6	* Lanthanide series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	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 173.05	71 Lu 174.97
7	# Actinide series	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)	103 Lr (262)

Group IIIB

– Representative
– Transition
– Inner Transition

semimetals
nonmetals
O metal

The Periodic Table

Groups- vertical columns of the periodic table (labeled IA to VIIIA and IB to VIIIB)- elements in the same group have similar properties

Periods- Horizontal rows of the periodic table (labeled 1 through 7

Representative elements- Group A elements

- **Alkali metals- Group IA**
- **Alkaline Earth metals- Group IIA**
- **Halogens- Group VIIA**
- **Noble Gases- Group VIIIA**

Transition elements (metals)- Group B elements

Inner transition elements (metals)- Group IIIB, periods 6 and 7

<u>IONS-</u> Atom or group of atoms with a positive or negative charge due to loss or gain of electrons

<u>CATIONS</u>- Ion with a positive charge (loses electrons)

<u>ANIONS</u>- Ion with a negative charge (gains electrons) -change ending to -ide

Ion	Atomic #	Mass #	+ p^+	n^0	− e^-	Name
Na^{+1}	11	23	11	12	10	sodium ion
Ca^{+2}	20	40	20	20	18	calcium ion
I^{-1}	53	127	53	74	54	iodide
N^{-3}	7	14	7	7	10	nitride
O^{-2}	8	16	8	8	10	oxide

ATOMIC MASS- **The weighted average mass of all isotopes for a given element**

A weighted average is calculated using masses of all isotopes for an element and the relative abundance in which they occur in nature

Example:

Name	Symbol	Natural % abundance	Average atomic mass
Oxygen	^{16}O	99.759	.99759(16)
	^{17}O	0.037	.00037(17)
	^{18}O	0.204	+ .00204(18)
			16.00

To calculate average atomic mass:

Values can be compared with atomic mass values on the periodic table

Name	Symbol	Natural % abundance	Average atomic mass
Sulfur	^{32}S	95.00	
	^{33}S	0.76	
	^{34}S	4.22	32.09
	^{36}S	0.014	

s

p

3d

d

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.0079																	2 He 4.0026
2	3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
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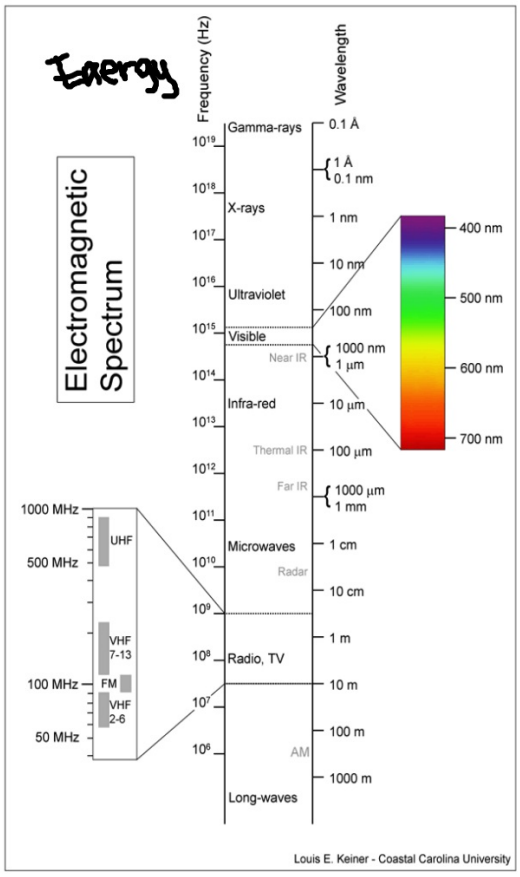
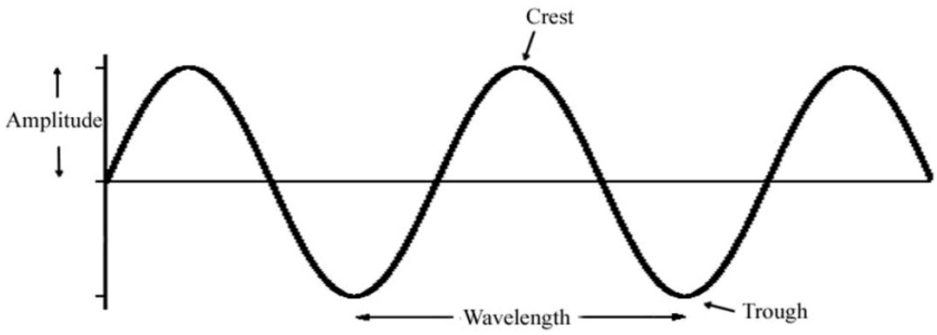
* Lanthanide series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97	4f
# Actinide series	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (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)	103 Lr (262)	5f

d¹ f¹ f

$$W\ \underbrace{1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6}\ 6s^2\ \underline{4f^{14}}\ 5d^4$$

Electromagnetic Radiation- any form of energy that exhibits wave-like behavior as it travels through space





Amplitude- vertical distance from the middle of the wave to the crest or trough

Wavelength- (symbolized λ- Greek letter lambda)- The distance between identical points on two identical waves- measured in units of distance

Frequency (symbolized ν- Greek letter nu)- The number of waves that pass a given point per unit time- measured in Hertz 1 Hz. = 1 cycle/sec.

Wavelength and frequency are inversely proportional and can be related by the formula:

wavelength

$$c = \lambda \nu$$ freq.

where c is the speed of light in a vacuum (a constant)

c= 3.00 X 10^{10} cm/sec

c= 3.00 X 10^{8} m/sec

Example:

Calculate the wavelength of radiation that has a frequency of ν **5.10 X 10^{14} Hz. In what part of the electromagnetic spectrum is this?**

$$c = \lambda \nu$$

$$\lambda = c/\nu = \frac{3 \times 10^{8}\ m/sec}{5.1 \times 10^{14}\ Hz\ 1/sec} = 5.88 \times 10^{-7}\ m$$

visible light

Energy (E) **(measured in Joules)**

Two formulas for energy:

$$E = h\nu$$ **where h is Planck's constant**

$h = 6.626 \times 10^{-34}$ Joule-sec.

Energy

Rearranging $c = \lambda\nu$, we get

$$E = \frac{hc}{\lambda}$$

$\nu = c/\lambda$

Calculate the energy of radiation with a frequency of 5.7 X 10^{20} Hz.

$E = h\nu$

$E = (6.626 \times 10^{-34}\ J \cdot sec)(5.7 \times 10^{20}\ 1/sec)$

$E = 3.78 \times 10^{-13}\ J$

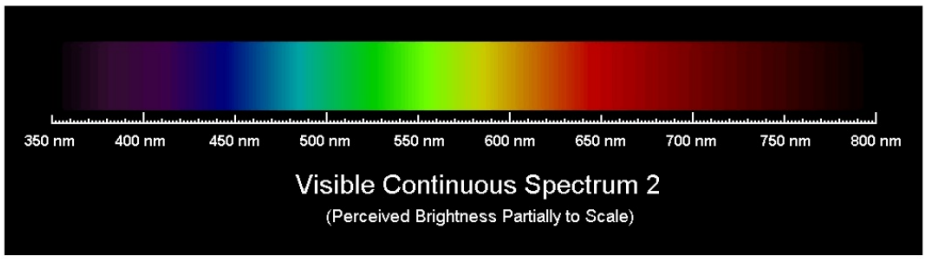
Calculate wavelength when the energy is 67 Joules.

$E = hc/\lambda \qquad \lambda = \frac{hc}{E}$

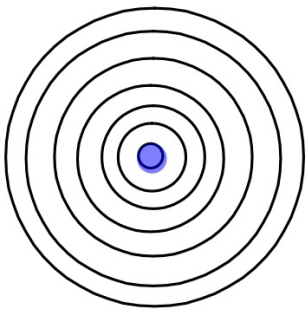
$\lambda = \frac{(6.626 \times 10^{-34}\ J \cdot sec)(3 \times 10^{8}\ m/sec)}{67\ J}$

$= 2.97 \times 10^{-27}\ m$

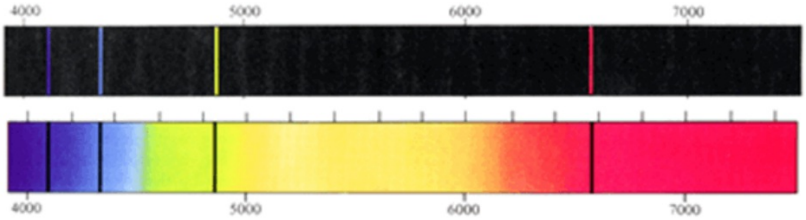
Continuous spectrum- spectrum in which all wavelengths in a given range are included



Energy level- region around the nucleus of an atom where an electron is likely to be moving- atoms have <u>quantized</u> energy levels (set amounts of energy)



<u>Atomic emission spectrum</u>- line spectra emitted by substances when energy is added to an atom and electrons move from higher energy levels back to their ground states- discrete amounts of energy released- each element has a unique pattern like a fingerprint



The Hydrogen Spectrum
Above: Emission
Below: Absorption

Hydrogen spectrum:
Lyman series- ultraviolet part of spectrum
Balmer series- visible parts of spectrum
Paschen series- infrared parts of spectrum

Arrangement of electrons in atoms

Energy levels- designated by principal quantum numbers n=1,2,3,4,5,6... (smaller numbers indicate closer proximity to nucleus)

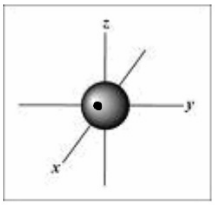
Energy sublevels- located within each energy level- 4 types based on the type of cloud shapes present (designated by 4 letters- s,p,d,f)

Electron cloud

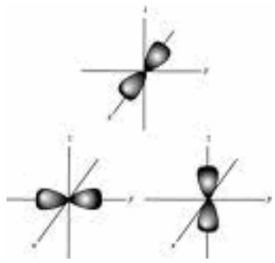
Atomic orbitals- region in space where there is a high probability of finding an electron- Each orbital can have a maximum of 2 electrons

Atomic orbitals

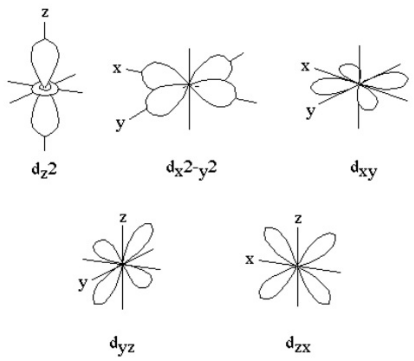
s orbital- spherical shape- 1 orbital (max 2 electrons)



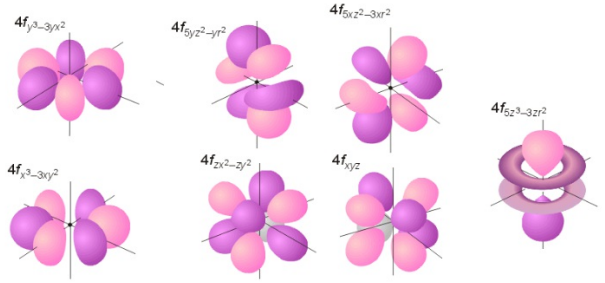
p orbitals- dumbbell shape- 3 orbitals (max 6 electrons)



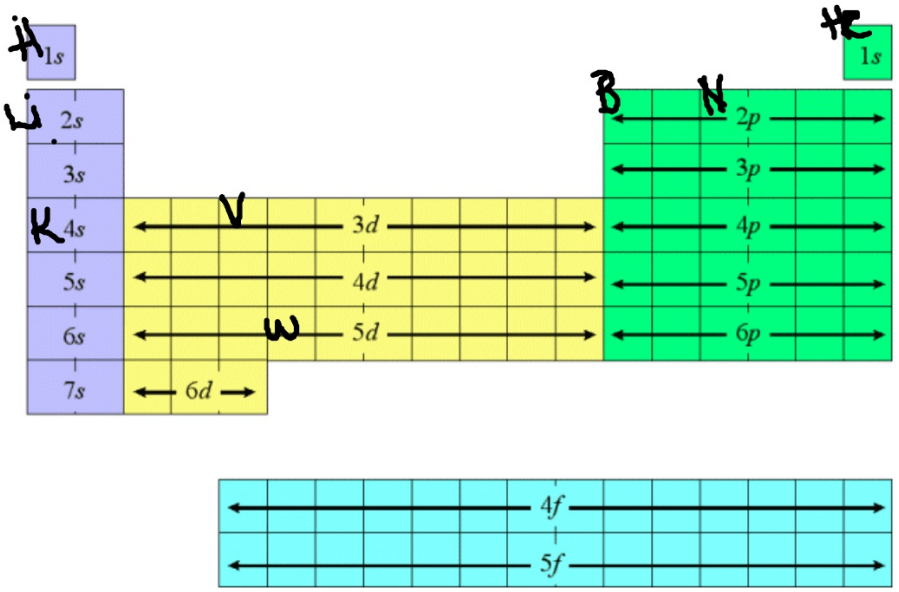
d orbitals- more complex shape- 5 orbitals (max 10 electrons)



f orbitals- most complex- 7 orbitals (max 14 electrons)



Energy level	# of sublevels	Type of sublevel	# of elec.
n=1	1	1s	2
n=2	2	2s, 2p	8
n=3	3	3s, 3p, 3d	18
n=4	4	4s, 4p, 4d, 4f	32



N $1s^2 2s^2 2p^3$

Li $1s^2 2s^1$

Be $1s^2 2s^2$

B $1s^2 2s^2 2p^1$

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

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

W

<u>Electron configuration</u>- the distribution of electrons among the various orbitals in an atom or molecule

Rules for filling atomic orbitals:

<u>The Aufbau Principle</u>: Electrons enter orbitals of lowest energy first (see periodic table diagram for order of energy)

Ex. Hydrogen- 1 electron in the 1s orbital

Electron configuration is written $1s^1$

Energy level

sublevel

# of electrons

He $1s^2$

Li

Be

B

K

V

W

Shortcut electron configurations

Use the noble gas (Group VIIIA element) that comes just before in brackets [ ]. Write only the additional orbits that come after the noble gas.

[Ne]
$1s^2 2s^2 2p^6$

Example: Mg [Ne] $3s^2$

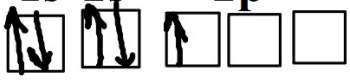
V [Ar] $4s^2 3d^3$

W [Xe] $6s^2 4f^{14} 5d^4$

<u>Pauli Exclusion Principle</u>- An atomic orbital may describe at most two electrons. To occupy the same orbital, two electrons must have opposite spin.

Orbital diagrams- use boxes or lines to represent each orbital, arrows to represent each electron

s - 1 p - 3 d 5 f - 7

Element	Elec. configuration	Orbital diagram
Hydrogen	$1s^1$	1s
Helium	$1s^2$	1s
Beryllium	$1s^2 2s^2$	1s 2s
Boron	$1s^2 2s^2 2p^1$	1s 2s 2p 

<u>Hund's Rule</u>- when electrons occupy orbitals of equal energy, one electron enters each orbital until all the orbitals contain one electron with spins parallel

Element	Elec. configuration	Orbital diagram
Carbon	$1s^2 2s^2 2p^2$	1s 2s 2p
Oxygen	$1s^2 2s^2 2p^4$	1s 2s 2p

$3d^4$

Quantum numbers- used to describe the distribution of electrons in atoms

Principal Quantum Number (n)- corresponds with the energy level number

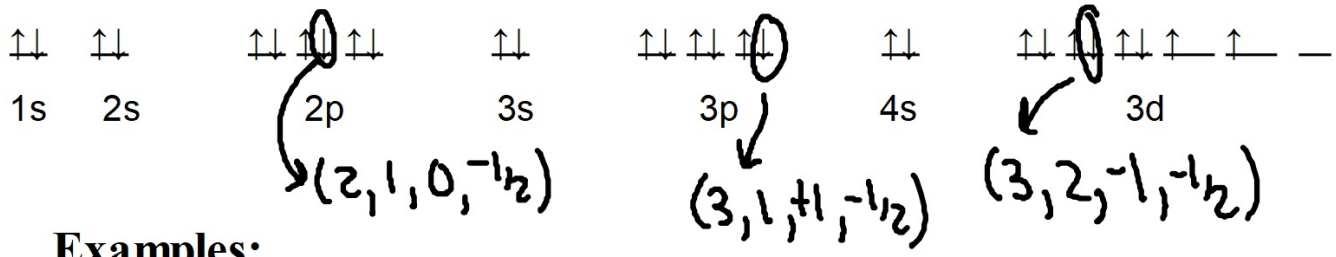
Angular Momentum Quantum Number (ℓ)- tells the shape of the orbital

ℓ	0	1	2	3	4	5
	s	p	d	f	g	h

Magnetic quantum number (m_ℓ)- describes the orientation in space-- $2\ell + 1$ values of m_ℓ or same as number of orbitals in the sublevel

s(1)				0			
p(3)			-1	0	1		
d(5)		-2	-1	0	1	2	
f(7)	-3	-2	-1	0	1	2	3

Electron Spin Quantum Number (m_s)- either +1/2 or -1/2 depending on spin of electrons (clockwise or counterclockwise)



Examples:

Write all possible four quantum number combinations for an electron in a 3p orbital

(3,1,-1,+1/2) (3,1,0,+1/2) (3,1,-1,+1/2)

(3,1,-1,-1/2) (3,1,0-1/2) (3,1,-1,-1/2)

Exceptional electron configurations

Chromium
Expected $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$
Actual $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

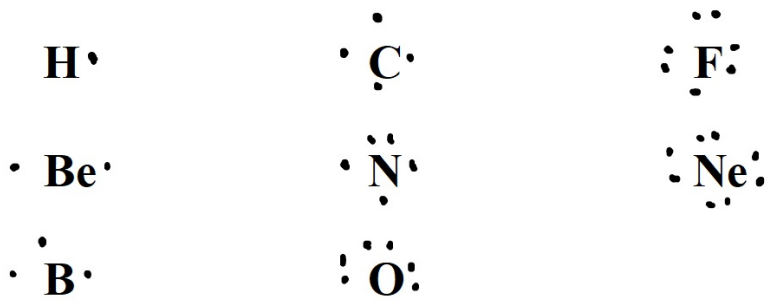
Copper
Expected $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$
Actual $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$

Why?
Filled energy levels are more stable than partially filled sublevels.

<u>Valence electrons</u>- the electrons in the highest occupied energy level of an atom; those involved in bonding

For representative elements- the number of valence electrons is the same as the group number (Roman numeral)

<u>Electron dot structure</u>- representation that depicts valence electrons as dots around the element's symbols



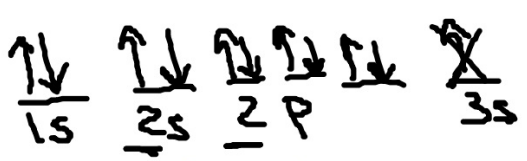
Stable electron configurations for cations or anions

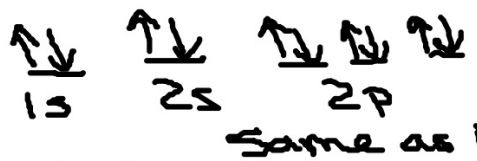
<u>Octet rule</u>- atoms tend to form ions so that they have eight electrons in their outer shell (same as a noble gas)

metals – lose elec. nonmetals – gain elec.

Sodium atom **Sodium ion** Na^{+1}

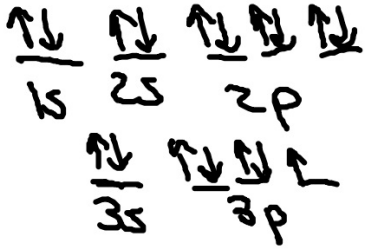
$1s^2 2s^2 2p^6 3s^1$

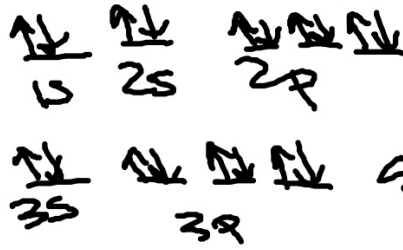




same as Ne

Chlorine atom **Chlorine ion** Cl^{-1}





same as Ar

Periodicity

Periodic table- organizes elements according to similar properties

History
1860s- first organization by Mendeleev (Mendeleev's grouping was amazingly similar to present groupings

http://corrosion-doctors.org/Periodic/Periodic-Mendeleev.htm

1913- Henry Mosely determined atomic numbers of elements and arranged atoms in order of increasing atomic number

Periodic Law- when the elements are arranged in order of increasing atomic number, there is a periodic pattern in their physical and chemical properties

Trends in Atomic Size

covalent atomic radius- half the distance between the nuclei of two atoms in a homonuclear diatomic molecule
-- *This is one way to estimate the size of an atom due to the fact that the radius cannot be determined directly because an atom does not have a sharply defined boundary*

Group Trends
Atomic size increases as we move down a group because electrons are added to higher energy levels as we move down

Periodic Trends
Atomic size decreases from left to right across a period. Electrons and protons are added as you move across a period. The effect of increasing nuclear charge on the outermost electrons is to pull them closer to the nucleus.

Trend in Atomic Size

Period

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	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)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (270)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Uub** (285)	113 **Uut** (284)	114 **Uuq** (289)	115 **Uup** (288)	116 **Uuh** (291)		118 **Uuo** (294)

* Lanthanide series	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	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** 173.05	71 **Lu** 174.97
# Actinide series	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)	103 **Lr** (262)

Increasing trend

<u>Ionization energy</u>- the energy to remove and electron from a gaseous atom

$$Na\ (g) \rightarrow Na^{+1} + e^{-}$$

<u>First ionization energy</u>- energy to remove first electron

Group IA- greatest increase from 1st to 2nd ion. en.

<u>Second ionization energy</u>- energy to remove 2nd electron

Group IIA- greatest increase from 2nd to 3rd ion en.

<u>Group trend</u>

Decreases down a group because size increases as you move down so outermost electrons are farther away from nucleus

<u>Periodic trend</u>

Increases from left to right because nuclear attraction increases as you go from left to right- more difficult to remove elec.

<u>Electronegativity</u>- the tendency of an atom to attract electrons to itself when chemically combined with another element (closely tied to ionization energy and electron affinity)

<u>Group trend</u>

Decrease down a group

<u>Periodic trend</u>

Increases left to right

Trend for Ionization energy, ~~Electron affinity~~, and Electronegativity

Period

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71 *	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)
87 Fr (223)	88 Ra (226)	89-103 #	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (270)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (291)		118 Uuo (294)

* Lanthanide series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	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 173.05	71 Lu 174.97
# Actinide series	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)	103 Lr (262)

Increasing trend

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

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

Br $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$

Ba $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2$

Np $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2$

$6d^1 5f^4$

Co [Ar] $4s^2 3d^7$

Ag [Kr] $5s^2 4d^9$

Te [Kr] $5s^2 4d^{10} 5p^4$

Ra [Rn] $7s^2$

Lr [Rn] $7s^2 \underline{6d^1} 5f^{14}$