PERIODIC TABLE

NONMETALS

METALLOIDS

METALS

Period	1 I A	2 II A	3 III B	4 IV B	5 V B	6 VI B	7 VII B	8 VIII	9 VIII	10 VIII	11 I B	12 II B	13 III A	14 IV A	15 V A	16 VI A	17 VII A	18 0
1	1 **H** hydrogen 1.008																	2 **He** helium 4.003
2	3 **Li** lithium 6.941	4 **Be** beryllium 9.012											5 **B** boron 10.81	6 **C** carbon 12.01	7 **N** nitrogen 14.01	8 **O** oxygen 16.00	9 **F** flourine 19.00	10 **Ne** neon 20.18
3	11 **Na** sodium 22.99	12 **Mg** magnesium 24.31											13 **Al** aluminum 26.98	14 **Si** silicon 28.09	15 **P** phosphorous 30.97	16 **S** sulfur 32.07	17 **Cl** clorine 35.45	18 **Ar** argon 39.95
4	19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.88	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	35 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.39	31 **Ga** gallium 69.72	32 **Ge** germanium 72.61	33 **As** arsenic 74.92	34 **Se** selenium 78.96	35 **Br** bromine 79.90	36 **Kr** krypton 83.80
5	37 **Rb** rubidium 85.47	38 **Sr** strontium 87.62	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.94	43 **Tc** technetium 97.91	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
6	55 **Cs** cesium 132.9	56 **Ba** barium 137.3	71 **Lu** lutetium 175.0	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.9	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium 209	85 **At** astatine 210.0	86 **Rn** radon (222)
7	87 **Fr** francium 223.0	88 **Ra** radium 226.0	103 **Lr** lawrencium 262.1	104 **Unq** unnilquadium (261)	105 **Unp** unnilpentium (262)	106 **Unh** unnilhexium (263)	107 **Uns** (262)	108 **Uno** (265)	109 **Une** (266)									
	Alkali Metals	Alkaline Earth Metals															Halogens	Noble Gases

Series														
Lanthanide series	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0
Actinide series	89 **Ac** actinium 227.0	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium 237.0	94 **Pu** plutonium 244.1	95 **Am** americium 243.1	96 **Cm** curium 247.1	97 **Bk** berkelium 247.1	98 **Cf** californium 251.1	99 **Es** einsteinium 252.1	100 **Fm** fermium 257.1	101 **Md** mendelevium 258.1	102 **No** nobelium 259.1

ATOMS AND QUANTUM MECHANICS

Atoms contain a **nucleus**, **core electrons**, and **valence electrons**. Electrons have orbital angular momentum and a spin angular momentum. The spin may be "up" or "down".

A **covalent bond** is formed when two atoms (usually nonmetals) *share* electrons. An **ionic bond** results from the *transfer* of electrons. The group number on the periodic table indicates the number of electrons available for covalent bonding. The elements of group IV are elemental semiconductors (carbon, silicon, germanium). Sp^3 means it can have 4 bonds. Semiconductor compounds must be covalently bonded. MgO and NaCl are not semiconductors because they are salts, ionically bonded.

Valence electrons are electrons in the outer shell of an atom that are responsible for the chemical properties of the atom.

The **metalloids** are not metals because there is a gap between the bonding states and the non-bonding states. **Metalloids** have a small **energy gap**. **Nonmetals** (Insulators) have a large energy gap. In **metals** there is overlap between bonding states.

Quantum mechanics is a theory of matter that is based on the concept of the possession of **wave properties** by elementary particles, that affords a mathematical interpretation of the structure and interactions of matter on the basis of these properties, and that incorporates within it quantum theory and the uncertainty principle — called also **wave mechanics**.

ARRANGEMENT OF ELECTRONS

An **orbital** is the volume in space where an electron of particular energy is likely to be found. An electron in one orbital will have a different energy than an electron in another orbital.

Electron energies are said to be **quantized**, that is, they have different sets of energies. If an electron loses or gains energy, it will do so only in regular or set quantities. When all of the electrons in an atom are in their lowest possible levels or positions, the atom is said to be in the **ground state**. When one or more of the electrons are in higher energy levels, the atom is said to be in the **excited state**.

Four **quantum numbers** [**n, l, m, s**] define the orbital location of an electron:

The first shell, which is indicated by **n=1**, contains one s sublevel. The s sublevel is spherical in shape and is indicated by **l**=**0** (that's an el). **l** is the **orbital angular momentum** and may be an integer from **0** to **n-1**.

The second shell, which is indicated by n=2, contains an s and a p sublevel. There are three orbitals in a p sublevel. They are shaped like ∞. l=1 indicates a p sublevel and m_l = **-1,0,1** are the three sublevels. **m** is the **azimuthal orbital angular momentum quantum number** and may be an integer from **–l** to **l**.

The third shell, which is indicated by n=3, contains an s sublevel, a p sublevel, and a d sublevel. A d sublevel is indicated by l=2 and contains 5 orbitals. Don't worry about the shapes of these orbitals.

This pattern of shell construction continues with an f sublevel, indicated by l=3, containing 7 orbitals, a g sublevel, indicated by l=4, containing 9 orbitals, and an h sublevel, indicated by l=5, containing 11 orbitals.

An orbital may have zero, one, or two electrons. The particular electron is indicated by a **spin angular momentum quantum number**, m_s or just **s**, which may be equal to -½ or +½

QUANTUM NUMBERS	
n	principal quantum number
l	orbital angular momentum, 0 to n-1
m_l or m	is the azimuthal orbital angular momentum quantum number and represents projection onto an axis, $-l \le m \le l$
m_s or s	spin degeneracy, ±½

By the **Aufbau Principle**, electrons are put into lowest orbitals first.

By **Hund's Rule**, when electrons are put into orbitals having the same energy (degenerate orbitals), one electron is put into each orbital before putting a second electron into an orbital. For example, a given p sublevel contains 3 *degenerate* orbitals. One electron will be placed in each of these orbitals before a second electron is placed in any of them.

Atoms with unpaired electrons are **paramagnetic**. Paramagnetic materials are weakly magnetized when brought into proximity to a magnet.

Atoms with no unpaired electrons are **diamagnetic**.

An **octet** has all orbitals in the first two shells filled.

By the **Pauli Exclusion Principal**, no 2 electrons in a given atom can have all 4 quantum numbers alike.

ORBITAL NOTATION

Orbital Notation example:

Ti Titanium	↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑ ↑
	1*s*	2*s*	2*p*	3*s*	3*p*	4*s*	3*d*

Orbital Diagram example:

Ti Titanium	[↑↓]	[↑↓]	[↑↓][↑↓][↑↓]	[↑↓]	[↑↓][↑↓][↑↓]	[↑↓]	[↑][↑]
	1s	2s	2p	3s	3p	4s	3d

Electron Configuration Notation example; note the order by shell number:

Ti Titanium $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

Abbreviated Orbital Notation example; the symbol for the noble gas preceeding the element is written in brackets (this is called the core), then additional electrons are shown following:

Ti Titanium [Ar]	↑↓	↑ ↑
	4*s*	3*d*

Abbreviated Electron Configuration Notation example:

Ti Titanium [Ar] $3d^2\ 4s^2$

Ionization energies generally decrease to the lower left. This is because those elements tend to have more shells so that the outer electrons are less tightly held.

When an atom loses electrons this happens in the reverse order of electron configuration notation. Outermost electrons leave the atom first, even though a lower shell might not be filled. In the case of our Titanium example, electrons would leave the 4s shell first although the 3d shell is not filled. Returning electrons fill the previously vacated spots first, then additional filling is according to Hund's Rule.

electron affinity: The measure of an atom's tendency to gain an electron. Thermal energy is released from most atoms when they gain an electron. Exothermic. The higher the electron affinity number, the more likely to gain an electron.

atomic radii: *Main* group radii generally increase to the lower left. Two factors influence the size of the radii:

1) The attraction of the positively charged nucleus to the negatively charged electrons
2) The negatively charged electrons tend to repel each other.

Additional shells tend to resist the effect of 1) due to **electron shielding**. The pull of the nucleus on the outer electrons is partially blocked by the inner electrons.

CONFIGURATION FOR ATOMS IN GROUND STATE

ATOMIC #	ELEMENT		n=1	n=2		n=3			n=4		SHORTHAND NOTATION
			1s	2s	2p	3s	3p	3d	4s	4p	
			NUMBER OF ELECTRONS								
1	H	hydrogen	1								$1s^1$
2	He	helium	2								$1s^2$
3	Li	lithium	2	1							$1s^2$ $2s^1$
4	Be	berylium	2	2							$1s^2$ $2s^2$
5	B	boron	2	2	1						$1s^2$ $2s^2$ $2p^1$
6	C	carbon	2	2	2	helium core,					$1s^2$ $2s^2$ $2p^2$
7	N	nitrogen	2	2	3	2 electrons					$1s^2$ $2s^2$ $3p^3$
8	O	oxygen	2	2	4						$1s^2$ $2s^2$ $2p^4$
9	F	flourine	2	2	5						$1s^2$ $2s^2$ $2p^5$
10	Ne	neon	2	2	6						$1s^2$ $2s^2$ $2p^6$
11	Na	sodium				1					[Ne] $3s^1$
12	Mg	magnesium				2					[Ne] $3s^2$
13	Al	aluminum				2	1				[Ne] $3s^2$ $3p^1$
14	Si	silicon	neon core,			2	2				[Ne] $3s^2$ $3p^2$
15	P	phosphorous	10 electrons			2	3				[Ne] $3s^2$ $3p^3$
16	S	sulfur				2	4				[Ne] $3s^2$ $3p^4$
17	Cl	chlorine				2	5				[Ne] $3s^2$ $3p^5$
18	Ar	argon				2	6				[Ne] $3s^2$ $3p^6$
19	K	potasium							1		[Ar] $4s^1$
20	Ca	calcium							2		[Ar] $4s^2$
21	Sc	scandium						1	2		[Ar] $3d^1$ $4s^2$
22	Ti	titanium						2	2		[Ar] $2d^2$ $4s^2$
23	V	vanadium						3	2		[Ar] $3d^3$ $4s^2$
24	Cr	chromium						5	1		[Ar] $3d^5$ $4s^1$
25	Mn	manganese						5	2		[Ar] $3d^5$ $4s^2$
26	Fe	iron						6	2		[Ar] $3d^6$ $4s^2$
27	Co	cobalt				argon core,		7	2		[Ar] $3d^7$ $4s^2$
28	Ni	nickel				18 electrons		8	2		[Ar] $3d^8$ $4s^2$
29	Cu	copper						10	1		[Ar] $3d^{10}$ $4s^1$
30	Zn	zinc						10	2		[Ar] $3d^{10}$ $4s^2$
31	Ga	galium						10	2	1	[Ar] $3d^{10}$ $4s^2$ $4p^1$
32	Ge	germanium						10	2	2	[Ar] $3d^{10}$ $4s^2$ $4p^2$
33	As	arsenic						10	2	3	[Ar] $3d^{10}$ $4s^2$ $4p^3$
34	Se	selenium						10	2	4	[Ar] $3d^{10}$ $4s^2$ $4p^4$
35	Br	bromine						10	2	5	[Ar] $3d^{10}$ $4s^2$ $4p^5$
36	Kr	krypton						10	2	6	[Ar] $3d^{10}$ $4s^2$ $4p^6$

ELECTRON CONFIGURATION WORKSHEET

n=1	*n*=2				*n*=3									*n*=3															
l=0	*l*=0	*l*=1			*l*=0	*l*=1			*l*=2					*l*=0	*l*=1			*l*=2					*l*=3						
1s	2*s*	2*p*			3*s*	3*p*			*d*					4*s*	4*p*			4*d*					4*f*						
m=0	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=-3	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=+3
OO																													
OO	OO	OO	OO	OO																									
OO	OO	OO	OO	OO	OO	OO	OO	OO																					
OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO							

n=1	*n*=2				*n*=3									*n*=3															
l=0	*l*=0	*l*=1			*l*=0	*l*=1			*l*=2					*l*=0	*l*=1			*l*=2					*l*=3						
1s	2*s*	2*p*			3*s*	3*p*			*d*					4*s*	4*p*			4*d*					4*f*						
m=0	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=-3	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=+3
OO																													
OO	OO	OO	OO	OO																									
OO	OO	OO	OO	OO	OO	OO	OO	OO																					
OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO							

n=1	*n*=2				*n*=3									*n*=3															
l=0	*l*=0	*l*=1			*l*=0	*l*=1			*l*=2					*l*=0	*l*=1			*l*=2					*l*=3						
1s	2*s*	2*p*			3*s*	3*p*			*d*					4*s*	4*p*			4*d*					4*f*						
m=0	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=-3	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=+3
OO																													
OO	OO	OO	OO	OO																									
OO	OO	OO	OO	OO	OO	OO	OO	OO																					
OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO							

n=1	*n*=2				*n*=3									*n*=3															
l=0	*l*=0	*l*=1			*l*=0	*l*=1			*l*=2					*l*=0	*l*=1			*l*=2					*l*=3						
1s	2*s*	2*p*			3*s*	3*p*			*d*					4*s*	4*p*			4*d*					4*f*						
m=0	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=0	*m*=-1	*m*=0	*m*=+1	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=-3	*m*=-2	*m*=-1	*m*=0	*m*=+1	*m*=+2	*m*=+3
OO																													
OO	OO	OO	OO	OO																									
OO	OO	OO	OO	OO	OO	OO	OO	OO																					
OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO							

The purpose of this worksheet is to assist in the visualization of electron configuration in the atoms of elements. The presence of electrons can be indicated by filling in the appropriate Os. The first row of each table is suitable for only the elements of hydrogen and helium. The second row is appropriate for the helium core atoms up through neon (atomic numbers 3-10). The third row is appropriate for neon core atoms up through argon (atomic numbers 11-18).