EIT Review

Chemistry

Topics

I. Basic Concepts
II. Molecular Bonding
III. Ideal Gas Law
IV. Concentration Measurements & Solutions
V. Acids and Bases, pH
VI. Chemical Reactions
VII. Organic Chemistry

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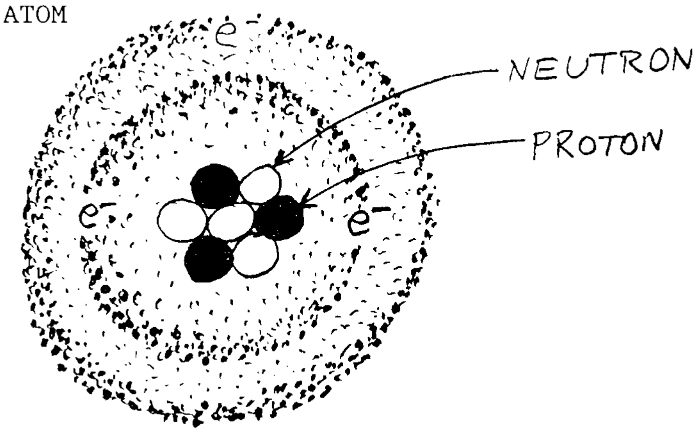
I. BASIC CONCEPTS

ANATOMY OF A LITHIUM ATOM



NUCLEUS

<u>Proton</u> - positively charged particle

1.6726×10^{-24} g = 1.00728 amu*

<u>Neutron</u> - neutral particle

1.6749×10^{-24} g = 1.00866 amu

ELECTRON - negatively charged particle

9.1096×10^{-28} g = 0.0005486 amu

<u>Inner Shell</u> - very stable electrons close to the nucleus

<u>Outer Shell</u> (a.k.a Valence Electrons) - reactive electrons which can combine with electrons from other atoms

CHEMISTRY is essentially the study of valence electrons and how atoms can combine together.

<u>Atomic Mass</u> - the total mass of protons + neutrons + electrons in a single atom

<u>Atomic Number</u> - the number of protons in the nucleus, a neutral atom has the same number of protons and electrons

<u>Element</u> - atoms with the same atomic number are grouped together and named as an element

<u>Isotope</u> - each element can have a variety of atomic masses

* amu (atomic mass unit) = 1/12 the mass of carbon-12

ISOTOPES OF CARBON

Isotope	Protons	Electrons	Neutrons	Half Life	Atomic Mass	Natural Abundance
C^{10}	6	6	4	19 s		
C^{11}	6	6	5	20 min		
C^{12}	6	6	6		12.00000^{+}	98.89%
C^{13}	6	6	7		13.00335	1.11%
C^{14}	6	6	8	5730 year		
C^{15}	6	6	9	2 s		
C^{16}	6	6	10	0.7 s		
					12.01115	100.00%

THE ELEMENTS

Atomic Number	Element	Symbol	Atomic Mass (amu)
1	Hydrogen	H	1.0079
2	Helium	He	4.00260
3	Lithium	Li	6.941
4	Beryllium	Be	9.01218
5	Boron	B	10.81
6	Carbon	C	12.011
7	Nitrogen	N	14.0067
8	Oxygen	O	15.9994
9	Fluorine	F	18.99840
10	Neon	Ne	20.179
11	Sodium	Na (natrium)	22.98977
12	Magnesium	Mg	24.305
13	Aluminum	Al	26.98154
14	Silicon	Si	28.086
15	Phosphorus	P	30.97376
16	Sulfur	S	32.06
17	Chlorine	Cl	35.453
18	Argon	Ar	39.948
19	Potassium	K (kalium)	39.098
20	Calcium	Ca	40.08
21	Scandium	Sc	44.9559
22	Titanium	Ti	47.90
23	Vanadium	V	50.9414
24	Chromium	Cr	51.996
25	Manganese	Mn	54.9380
26	Iron	Fe (ferrum)	55.847
27	Cobalt	Co	58.9332
28	Nickel	Ni	58.71
29	Copper	Cu (cuprum)	63.546
30	Zinc	Zn	65.38
31	Gallium	Ga	69.72
32	Germanium	Ge	72.59
33	Arsenic	As	74.9216

HALF LIFE

$$A \xrightarrow{k} B$$

$$r = -\frac{dA}{dt} = +\frac{dB}{dt} = kA$$

$$\frac{dA}{A} = -k\,dt$$

$$\int_{A_0}^{A} \frac{dA}{A} = \int_0^t -k\,dt = -k\int_0^t dt$$

$$\left[\ln A\right]_{A_0}^{A} = -k\left[t\right]_0^t$$

$$\left[\ln A - \ln A_0\right] = -k\left[t-0\right]$$

$$\ln\frac{A}{A_0} = -kt$$

$$\frac{A}{A_0} = e^{-kt}$$

$$\boxed{A = A_0 e^{-kt}}$$

@ τ (half life), $\frac{A}{A_0} = \frac{1}{2}$

$$\frac{1}{2} = e^{-k\tau}$$

$$\ln\frac{1}{2} = -k\tau$$

$$k = -\left(\ln\frac{1}{2}\right)\frac{1}{\tau} = +0.693\,\frac{1}{\tau}$$

$$\boxed{A = A_0 e^{-0.693\frac{t}{\tau}}}$$

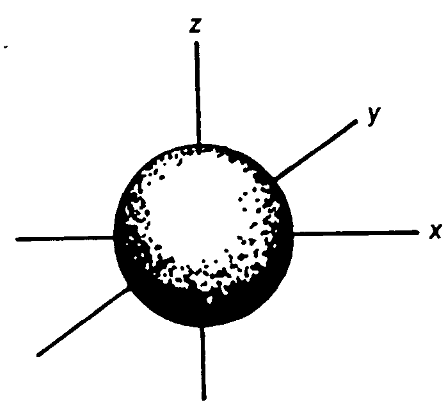
Atomic Number	Element	Symbol	Atomic Mass (amu)
34	Selenium	Se	78.96
35	Bromine	Br	79.904
36	Krypton	Kr	83.80
37	Rubidium	Rb	85.4678
38	Strontium	Sr	87.62
39	Yttrium	Y	88.9059
40	Zirconium	Zr	91.22
41	Niobium	Nb	92.9064
42	Molybdenum	Mo	95.94
43	Technetium	Tc	98.9062
44	Ruthenium	Ru	101.07
45	Rhodium	Rh	102.9055
46	Palladium	Pd	106.4
47	Silver	Ag (argentum)	107.868
48	Cadmium	Cd	112.40
49	Indium	In	114.82
50	Tin	Sn (stannum)	118.69
51	Antimony	Sb (stibium)	121.75
52	Tellurium	Te	127.60
53	Iodine	I	126.9045
54	Xenon	Xe	131.30
55	Cesium	Cs	132.9054
56	Barium	Ba	137.34
57	Lanthanum	La	138.9055
58	Cerium	Ce	140.12
59	Praseodymium	Pr	140.9077
60	Neodymium	Nd	144.24
61	Promethium	Pm	145
62	Samarium	Sm	150.4
63	Europium	Eu	151.96
64	Gadolinium	Gd	157.25
65	Terbium	Tb	158.9254
66	Dysprosium	Dy	162.50
67	Holmium	Ho	164.9304
68	Erbium	Er	167.26
69	Thulium	Tm	168.9342
70	Ytterbium	Yb	173.04
71	Lutetium	Lu	174.97
72	Hafnium	Hf	178.49
73	Tantalum	Ta	180.9479
74	Tungsten	W (wolfram)	183.85
75	Rhenium	Re	186.2
76	Osmium	Os	190.2
77	Iridium	Ir	192.22
78	Platinum	Pt	195.09
79	Gold	Au (aurum)	196.9665
80	Mercury	Hg (hydrargyrum)	200.59
81	Thallium	Tl	204.37
82	Lead	Pb (plumbum)	207.2
83	Bismuth	Bi	208.9804

Atomic Number	Element	Symbol	Atomic Mass (amu)
84	Polonium	Po	209.9829
85	Asatine	At	210
86	Radon	Rn	222.0175
87	Francium	Fr	223.0198
88	Radium	Ra	226.0254
89	Actinium	Ac	227.0278
90	Thorium	Th	232.0381
91	Protactinium	Pa	231.0359
92	Uranium	U	238.029
93	Neptunium	Np	237.0482
94	Plutonium	Pu	244
95	Americium	Am	243.0614
96	Curium	Cm	247
97	Berkelium	Bk	247.0702
98	Californium	Cf	251
99	Einsteinium	Es	254.0881
100	Fermium	Fm	257
101	Mendelevium	Md	258
102	Nobelium	No	255
103	Lawrencium	Lr	256
104	Kurchatovium	Ku	257
105	Hahnium	Ha	260

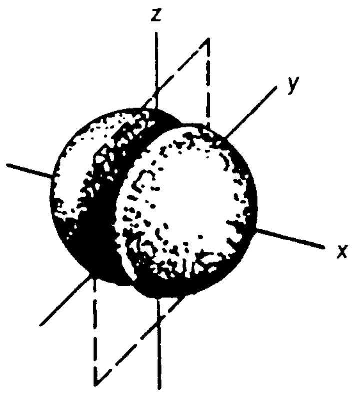
ELECTRON CONFIGURATION

The electrons "orbiting" the nucleus are confined to certain regions of space, that is, there is a greater probability of finding an electron in one region than another. To define the region where the electron will be found, it is necessary to solve the Schroedinger Equation. These regions, or "orbitals", are shown below:

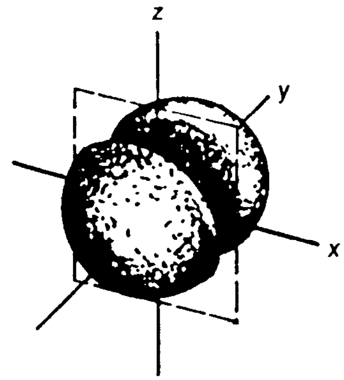
<u>s orbital</u>
(2 electrons)



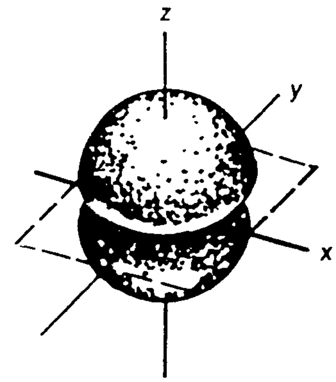
p orbital
(6 electrons)



$2p_x$

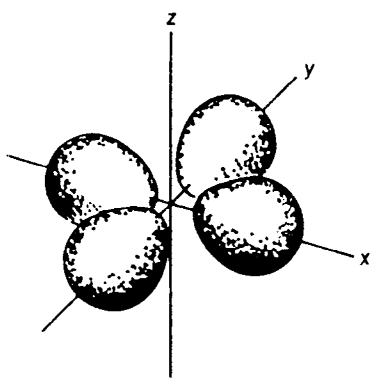


$2p_y$

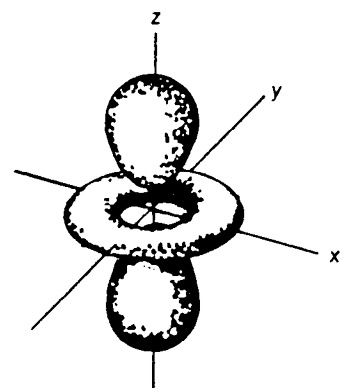


$2p_z$

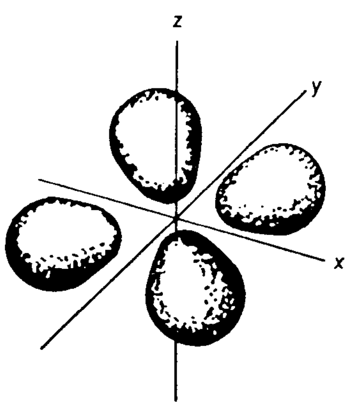
d orbital
(10 electrons)



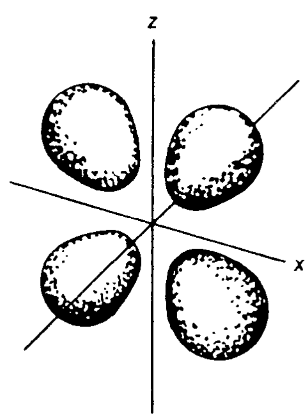
$3d_{x^2-y^2}$



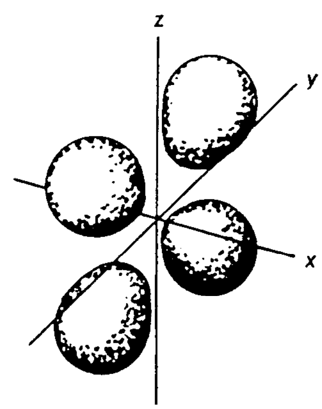
$3d_{z^2}$



$3d_{xy}$



$3d_{xz}$



$3d_{yz}$

f orbital
(14 electrons)

TOO COMPLEX TO SHOW

Each element has the following configuration.

Z	Element	$1s$	$2s$	$2p$	$3s$	$3p$	$3d$	$4s$	$4p$
1	H	1							
2	He	2							
3	Li	2	1						
4	Be	2	2						
5	B	2	2	1					
6	C	2	2	2					
7	N	2	2	3					
8	O	2	2	4					
9	F	2	2	5					
10	Ne	2	2	6					
11	Na	Neon shell			1				
12	Mg				2				
13	Al				2	1			
14	Si				2	2			
15	P				2	3			
16	S				2	4			
17	Cl				2	5			
18	Ar				2	6			
19	K	Argon shell						1	
20	Ca							2	
21	Sc						1	2	
22	Ti						2	2	
23	V						3	2	
24	Cr						5	1	
25	Mn						5	2	
26	Fe						6	2	
27	Co						7	2	
28	Ni						8	2	
29	Cu						10	1	
30	Zn						10	2	
31	Ga						10	2	1
32	Ge						10	2	2
33	As						10	2	3
34	Se						10	2	4
35	Br						10	2	5
36	Kr						10	2	6

(*Continued*)

Z	Element		4d	4f	5s	5p	5d	5f	6s	6p
37	Rb	Krypton shell			1					
38	Sr				2					
39	Y		1		2					
40	Zr		2		2					
41	Nb		4		1					
42	Mo		5		1					
43	Tc		6		1					
44	Ru		7		1					
45	Rh		8		1					
46	Pd		10							
47	Ag		10		1					
48	Cd		10		2					
49	In		10		2	1				
50	Sn		10		2	2				
51	Sb		10		2	3				
52	Te		10		2	4				
53	I		10		2	5				
54	Xe		10		2	6				
55	Cs	Xenon shell							1	
56	Ba								2	
57	La						1		2	
58	Ce			2					2	
59	Pr			3					2	
60	Nd			4					2	
61	Pm			5					2	
62	Sm			6					2	
63	Eu			7					2	
64	Gd			7			1		2	
65	Tb			9					2	
66	Dy			10					2	
67	Ho			11					2	
68	Er			12					2	
69	Tm			13					2	
70	Yb			14					2	
71	Lu			14			1		2	
72	Hf			14			2		2	
73	Ta			14			3		2	
74	W			14			4		2	
75	Re			14			5		2	
76	Os			14			6		2	
77	Ir			14			9			
78	Pt			14			9		1	

(Continued)

Z	Element		4f	5s	5p	5d	5f	6s	6p	6d	7s
79	Au	Xenon shell	14			10		1			
80	Hg		14			10		2			
81	Tl		14			10		2	1		
82	Pb		14			10		2	2		
83	Bi		14			10		2	3		
84	Po		14			10		2	4		
85	At		14			10		2	5		
86	Rn		14			10		2	6		
87	Fr	Radon shell									1
88	Ra										2
89	Ac									1	2
90	Th									2	2
91	Pa						2			1	2
92	U						3			1	2
93	Np						4			1	2
94	Pu						5			1	2
95	Am						6			1	2
96	Cm						7			1	2
97	Bk						8			1	2
98	Cf						9			1	2

The electrons in the inner shells are basically inert. It's the electrons in the outer shell which give the atom its unique properties. Elements with the same electronic configuration in the outer shells have similar properties. The elements in the columns of the "Periodic Table" (see next page) are similar.

Group 0 (Noble Gases) - inert since outer shell is completely filled

Group IA (Alkali Metals) - metallic character, causes water to become basic

Group VIIA (Halogens) - nonmetallic character, combines with hydrogen readily (e.g. HCl) and is acidic in water

<u>Metals</u> have a silvery luster and are good conductors of heat and electricity since the outermost electrons are loosely bound. Elements to the left of the heavy line are metals and elements to the right are nonmetals.

The Periodic Chart of the Elements

I A	II A	III B	IV B	V B	VI B	VII B		VIII B		I B	II B	III A	IV A	V A	VI A	VII A	0
1 **H** 1.0080																	2 **He** 4.003
3 **Li** 6.940	4 **Be** 9.013											5 **B** 10.82	6 **C** 12.011	7 **N** 14.008	8 **O** 16.000	9 **F** 19.00	10 **Ne** 20.183
11 **Na** 22.991	12 **Mg** 24.32											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.975	16 **S** 32.066	17 **Cl** 35.457	18 **Ar** 39.944
19 **K** 39.100	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.95	24 **Cr** 52.01	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.94	28 **Ni** 58.71	29 **Cu** 63.54	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.60	33 **As** 74.91	34 **Se** 78.96	35 **Br** 79.916	36 **Kr** 83.80
37 **Rb** 85.48	38 **Sr** 87.63	39 **Y** 88.92	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** (99)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.4	47 **Ag** 107.880	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.70	51 **Sb** 121.87	52 **Te** 127.61	53 **I** 126.91	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.36	57 ***La** 138.92	72 **Hf** 178.50	73 **Ta** 180.95	74 **W** 183.86	75 **Re** 186.22	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.09	79 **Au** 197.0	80 **Hg** 200.61	81 **Tl** 204.39	82 **Pb** 207.21	83 **Bi** 209.00	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **†Ac** (227)	104 **Ku** (261)	105 **Ha** (260)													

*** Lanthanides**	58 **Ce** 140.13	59 **Pr** 140.92	60 **Nd** 144.27	61 **Pm** (147)	62 **Sm** 150.35	63 **Eu** 152.0	64 **Gd** 157.26	65 **Tb** 158.93	66 **Dy** 162.51	67 **Ho** 164.94	68 **Er** 167.27	69 **Tm** 168.94	70 **Yb** 173.04	71 **Lu** 174.99
† Actinides	90 **Th** (232)	91 **Pa** (231)	92 **U** 238.07	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (249)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (253)	101 **Md** (256)	102 **No** (253)	103 **Lw** (257)

<u>Electronegativity</u> describes the affinity that an element has for electrons. The Nobel laureate Linus Pauling has devised a 4-point scale for electronegativity. The higher number represents a greater affinity for electrons. Notice how the numbers increase from left to right and bottom to top.

INCREASE

1 H 2.1																	2 He —
3 Li 1.0	4 Be 1.5											5 B 2.0	6 C 2.5	7 N 3.0	8 O 3.5	9 F 4.0	10 Ne —
11 Na 0.9	12 Mg 1.2											13 Al 1.5	14 Si 1.8	15 P 2.1	16 S 2.5	17 Cl 3.0	18 Ar —
19 K 0.8	20 Ca 1.0	21 Sc 1.3	22 Ti 1.5	23 V 1.6	24 Cr 1.6	25 Mn 1.5	26 Fe 1.8	27 Co 1.8	28 Ni 1.8	29 Cu 1.9	30 Zn 1.6	31 Ga 1.6	32 Ge 1.8	33 As 2.0	34 Se 2.4	35 Br 2.8	36 Kr —
37 Rb 0.8	38 Sr 1.0	39 Y 1.2	40 Zr 1.4	41 Nb 1.6	42 Mo 1.8	43 Tc 1.9	44 Ru 2.2	45 Rh 2.2	46 Pd 2.2	47 Ag 1.9	48 Cd 1.7	49 In 1.7	50 Sn 1.8	51 Sb 1.9	52 Te 2.1	53 I 2.5	54 Xe —
55 Cs 0.7	56 Ba 0.9	57-71 — 1.1-1.2	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.8	83 Bi 1.9	84 Po 2.0	85 At 2.2	86 Rn —
87 Fr 0.7	88 Ra 0.9	89-103 Ac-Lr 1.1-1.3	104 Ku —	105 Ha —													

INCREASE

II. MOLECULAR BONDING

<u>Molecule</u> - an "aggregate" of atoms; the smallest unit of a macroscopic substance which retains all the chemical properties of the macroscopic substance

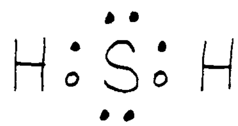
<u>Molecular Weight</u> (MW) - the sum total of all the atomic weights in the molecule

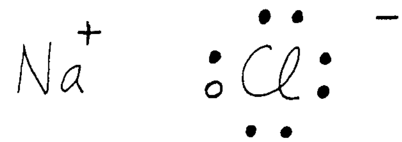
MW of $CaCl_2$ = 1(40.08) + 2(35.453) = 110.986

MW of CH_4 = 1(12.011) + 4(1.0079) = 16.0426

MW of $MgSO_4$ = 1(24.305) + 1(32.06) + 4(15.9994) = 120.3626

Elements combine to form molecules in order to fill their outer shell. Usually, this means the element will have eight electrons around it although in the case of hydrogen, it will only have two. If the elements have similar electronegativities, the bond is <u>covalent</u>. If the electo-negativites are very different, it is an <u>ionic</u> bond.



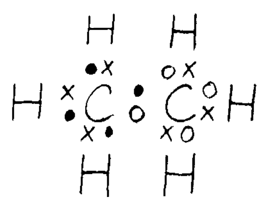


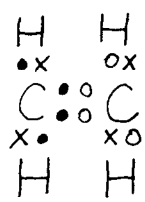
Covalent

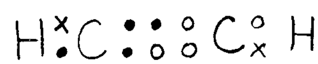
Ionic

Types of Covalent Bonds

Single	Double	Triple
H H H C - C H H H	H H C = C H H	H C ≡ C H

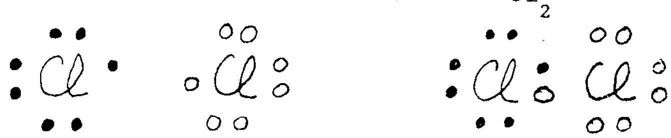






If an element has an incomplete outer shell, it is a <u>free</u> <u>radical</u> and is extremely reactive.

$Cl^{\cdot}$ + $Cl^{\cdot}$ ——> Cl_2



$O^{\cdot}$ + $O^{\cdot}$ ——> O_2

Many elements combine with themselves in order to fill the outer orbital shell.

N_2, O_2, halogens (F_2, Cl_2, Br_2, I_2)

Radicals

Some elements combine to form very stable species with a net charge

nitrate	sulfate	carbonate	phosphate
NO_3^-	SO_4^{2-}	CO_3^{2-}	PO_4^{3-}

III. GAS LAWS

Ideal Gas - 1. no intermolecular forces
2. gas molecules occupy no volume

Real gases behave as an ideal gase at low pressures. Noble gases behave like an ideal gas at higher pressures than most other gases.

$P\ V = n\ R\ T$ (Ideal Gas Law)

	Scientific Units	Engineering Units
P = absolute pressure	atm	psia
V = volume	L	ft^3
n = moles	gmol	lbmol
R = universal gas const	0.08205 atm L/gmol $^{\circ}K$	10.73 psia ft^3/lbmol $^{\circ}R$
T = absolute temperature	$^{\circ}K$	$^{\circ}R$

psia = psig + 14.69

$^{\circ}R = {^{\circ}F} + 459.67$

$^{\circ}K = {^{\circ}C} + 273.15$

$^{\circ}F = 1.8\ {^{\circ}C} + 32$

$^{\circ}C = ({^{\circ}F} - 32)/1.8$

gmol = 6.0222×10^{23} molecules = Avogadro's Number

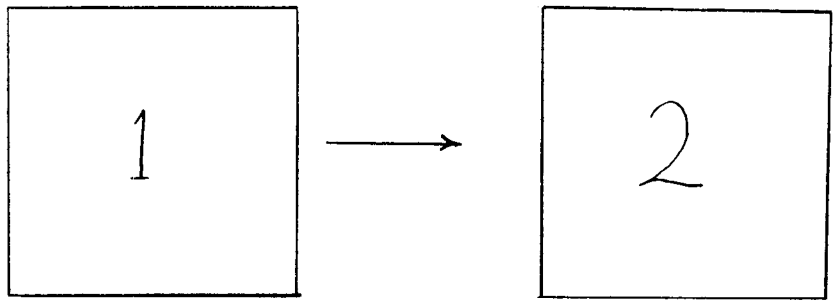
lbmol = 2.7316×10^{26} molecules

$$n = \frac{\text{actual weight}}{\text{molecular weight}}$$

Standard Temperature and Pressure (STP) = $0^{\circ}C$, 1 atm

$$\frac{V}{n} = \frac{R\ T}{P} = \frac{(0.08205 \text{ atm L/gmole } ^{\circ}K)\ (273.15\ ^{\circ}K)}{1 \text{ atm}} = 22.4 \text{ L/gmole}$$

Some Simple Relationships



	Const T	Const P	Const V
$\frac{V_1}{V_2}$	$\frac{P_2}{P_1}$	$\frac{T_1}{T_2}$	
$\frac{T_1}{T_2}$		$\frac{V_1}{V_2}$	$\frac{P_1}{P_2}$
$\frac{P_1}{P_2}$	$\frac{V_2}{V_1}$		$\frac{T_1}{T_2}$

Dalton's Law - the total pressure of a mixture of gases is the sum of the partial pressures of each gas

$$P = P_A + P_B + P_C + P_D + \cdots$$

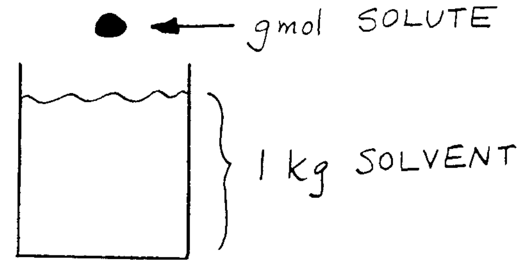
IV. CONCENTRATION MEASUREMENT

Solute - that which is dissolved (e.g. salt)

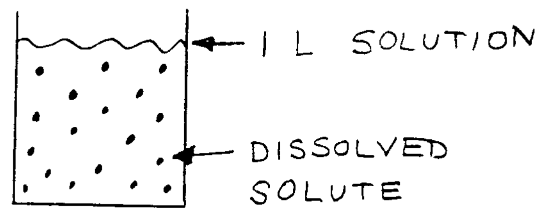
Solvent - that which does the dissolving (e.g. water)

Solution - the homogeneous mixture of solute and solvent

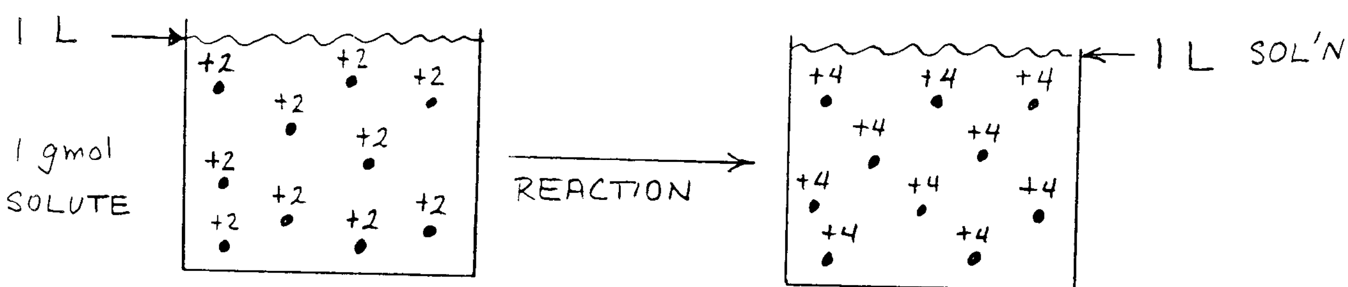
$$\text{(m) molality} = \frac{\text{gmol solute}}{\text{kg solvent}}$$



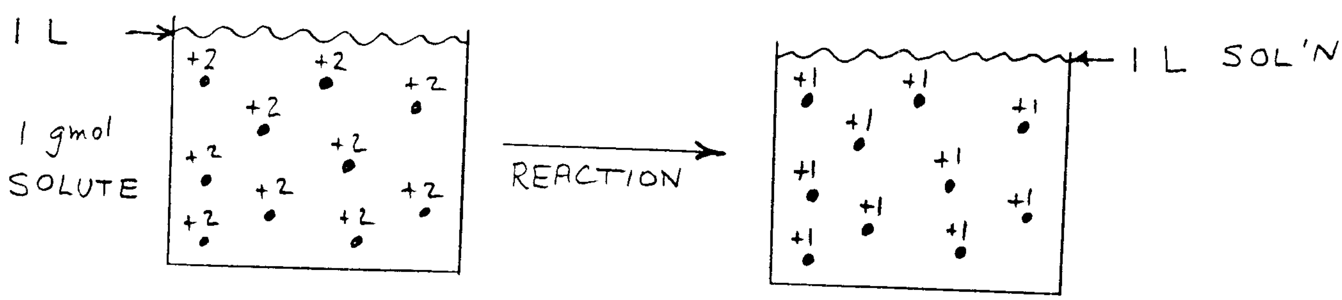
$$\text{(M) Molarity} = \frac{\text{gmol solute}}{\text{L solution}}$$



$$\text{(N) Normality} = \frac{\text{g mol equivalent electrons}}{\text{L solution}} = \frac{\text{gmol solute}}{\text{L solution}} \left|\begin{array}{c}\text{change}\\ \text{in}\\ \text{valence}\end{array}\right|$$



$$\text{NORMALITY} = \frac{1 \text{ gmol}}{\text{L SOL'N}} \times |4-2| = \frac{2 \text{ gmol equivalents}}{\text{L SOL'N}} = 2N$$



$$\text{NORMALITY} = \frac{1 \text{ gmol}}{\text{L SOL'N}} \times |1-2| = \frac{1 \text{ gmol equivalents}}{\text{L SOL'N}} = 1N$$

V. pH

Water dissociates into a proton and hydroxide group

$$H_2O \longleftrightarrow H^+ + OH^-$$

$$K_c = \frac{[H^+]\ [OH^-]}{[H_2O]} \qquad [\ ] = \text{molarity}$$

$$[H_2O] = 55.5555 \text{ gmol/L} = \text{const}$$

$$K_w = [H^+]\ [OH^-] = 10^{-14}$$

$$pH \equiv \log_{10}(1/[H^+])$$

$$pOH \equiv \log_{10}(1/[OH^-])$$

$$pH + pOH = 14$$

$pH > 7$ ($[OH^-] > [H^+]$) Alkaline

$pH < 7$ ($[OH^-] < [H^+]$) Acidic

<u>Sample Problem</u>: Calculate the pH of a 10 g/L NaOH solution. (Note: NaOH dissociates completely in water.)

MW of NaOH = 1 (22.98977) + 1 (15.99840) + 1 (1.0079) = 39.99607 g/gmol

$$[NaOH] = 10\ \frac{g}{L} \times \frac{\text{gmol}}{39.99607g} = 0.25 \text{ gmol/L}$$

$$[OH^-] = \frac{0.25 \text{ gmol NaOH}}{L} \times \frac{1 \text{ gmol } OH^-}{\text{gmol NaOH}} = 0.25 \text{ gmol/L}$$

$$pOH = \log_{10}\left(\frac{1}{0.25 \text{ gmol/L}}\right) = 0.602$$

$$pH = 14 - pOH = 14 - 0.602 = 13.398$$

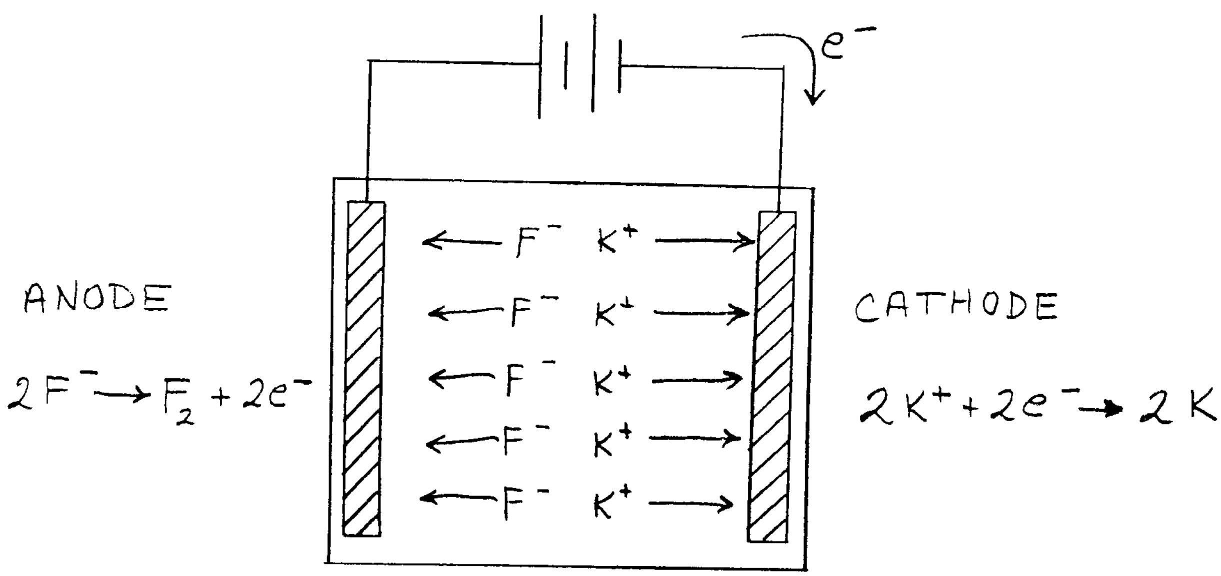
VI. CHEMICAL REACTIONS

In <u>chemical reactions</u>, elements (or molecules) rearrange themselves to form more stable (i.e., lower energy) molecules. The reaction is highly favored if electrons are transferred from an element which loosely binds its outer electrons (low electronegativity) to one which tightly binds its outer electrons (high electronegativity). The element (or compound) which donates the electron is called the <u>reducing agent</u>. The element (or compound) which receives the electron is called the <u>oxidizing agent</u>.

	Reducing Agent		Oxidizing Agent				
Highly Favored ↑	2 K	+	F_2	⟶	$2\ K^+$	+	$2\ F^-$
	2 Na	+	F_2	⟶	$2\ Na^+$	+	$2\ F^-$
↓ Least Favored	2 Li	+	F_2	⟶	$2\ Li^+$	+	$2\ F^-$

In the above reactions, fluorine "is reduced" and the alkali metal (K, Na, Li) "is oxidized."

This process can be reversed in an electrochemical cell.



<u>Cation</u> - a positive ion which is attracted to the cathode.

<u>Anion</u> - a negative ion which is attracted to the anode.

The concepts of oxidation/reduction do not only apply to ionic elements. Elements in covalent bonds can also be more higly reduced or oxidized.

$$
\begin{array}{ccccc}
\begin{array}{ccc} & H & \\ H & C & H \\ & H & \end{array} &
\begin{array}{ccc} & H & \\ H & C & OH \\ & H & \end{array} &
\begin{array}{ccc} & H & \\ H & C & = O \\ & & \end{array} &
\begin{array}{ccc} & OH & \\ H & C & = O \\ & & \end{array} &
O = C = O
\end{array}
$$

Reduced <——————————————————————————>Oxidized

<u>Combustion</u> - the burning of a fuel with oxygen

$$CH_4 + 2\ O_2 \longrightarrow CO_2 + 2\ H_2O + \text{Heat}$$

Balancing a Chemical Equation

1. write reactants on left side of arrow; products on right side of arrow
2. base calculation on one molecule of a reactant (or product) species; other species are a, b, c, etc.
3. write equations for each element as a matrix
4. solve matrix for a, b, c, etc.

$$H_2C{=}CH_2 + a\ O_2 \longrightarrow b\ CO_2 + c\ H_2O$$

C:	2	+ a (0)	=	b (1) + c (0)	=> b=2
H:	4	+ a (0)	=	b (0) + c (2)	=> c=2
O:	0	+ a (2)	=	b (2) + c (1)	=> a=3

$$H_2C{=}CH_2 + 3\ O_2 \longrightarrow 2\ CO_2 + 2\ H_2O$$

Reaction Kinetics

$$a\,A + b\,B \longleftrightarrow c\,C + d\,D$$

A. Elementary Reactions (goes exactly as written with no intermediates)

1. Gas Phase Reactions

reaction rate, R, may be written as

$$R = -\frac{dP_A}{a\,dt} = -\frac{dP_B}{b\,dt} = \frac{dP_C}{c\,dt} = \frac{dP_D}{d\,dt} = k\,P_A^a\,P_B^b - k'\,P_C^c\,P_D^d$$

where P is the partial pressure of the compound, k is the forward rate constant and k′ is the reverse rate constant.

At Equilibrium (R=0)

$$\frac{k}{k'} = \frac{P_C^c\,P_D^d}{P_A^a\,P_B^b} = K_p$$

$K_p \gg 1$; irreversible, favorable as written

$K_p \approx 1$; reversible

$K_p \ll 1$; irreversible, unfavorable as written

2. Liquid Phase Reactions

$$R = -\frac{dC_A}{a\,dt} = -\frac{dC_B}{b\,dt} = \frac{dC_C}{c\,dt} = \frac{dC_D}{d\,dt} = k\,C_A^a\,C_B^b - k'\,C_C^c\,C_D^d$$

where C is the concentration (molarity) of each chemical species.

At Equilibrium (R=0)

$$\frac{k}{k'} = \frac{C_C^c\,C_D^d}{C_A^a\,C_B^b} = K_c$$

3. Solid Phase Reactions

Any solid species which occur in the reaction do not appear in the equilibrium expression since the concentration of a solid is constant. This constant is incorporated into K_c.

B. Nonelementary Reactions (intermediates are involved)

Rate expressions must be determined experimentally. Equilibrium constants (K_p or K_c) are defined the same way.

Increasing temperature increases the rate exponentially. A rule of thumb is that for each $10^{\circ}C$ increase in temperature, the reaction rate doubles.

A catalyst provides an alternate reaction path which can increase the reaction rate by orders of magnitude without being consumed in the process. It increases the forward and reverse rate constant by the same amount so the equilibrium is not affected, just the speed with which the reaction gets there.

Exothermic Reaction - heat is evolved

$$aA + bB \longrightarrow cC + dD + \text{heat}$$

Endothermic Reaction - heat is required

$$\text{heat} + aA + bB \longrightarrow cC + dD$$

Le Chatelier's Principle - when a force is applied to a system at equilibrium, the system establishes a new equilibrium which minimizes the effects of the applied force.

Le Chatelier's Principle applied to chemical equilibrium:

exothermic reaction - favored at lower temperatures

endothermic reaction - favored at higher temperatures

increase in moles ($a + b < c + d$) - favored at lower pressures

decrease in moles ($a + b > c + d$) - favored at higher pressures

VII. ORGANIC CHEMISTRY

<u>Organic Chemistry</u> - study of carbon chemistry

Alkanes - single bonds in the carbon chain

n	Name	Formula
1	methane	CH_4
2	ethane	CH_3CH_3
3	propane	$CH_3CH_2CH_3$
4	butane	$CH_3CH_2CH_2CH_3$
5	pentane	$CH_3(CH_2)_3CH_3$
6	hexane	$CH_3(CH_2)_4CH_3$
7	heptane	$CH_3(CH_2)_5CH_3$
8	octane	$CH_3(CH_2)_6CH_3$
9	nonane	$CH_3(CH_2)_7CH_3$
10	decane	$CH_3(CH_2)_8CH_3$

Alkenes	$R\text{-}\overset{H}{C}=\overset{H}{C}\text{-}R'$	(double bond in the carbon chain)
Alkynes	$R\text{-}C\equiv C\text{-}R'$	(triple bond in the carbon chain)
Alcohol	R-OH	$H_3C\text{-}CH_2OH$ (ethanol)
Aldehyde	$R\text{-}\overset{O}{\overset{\Vert}{C}}H$	$H\overset{O}{\overset{\Vert}{C}}H$ (formaldehyde)
Carboxylic Acid	$R\text{-}\overset{O}{\overset{\Vert}{C}}OH$	$H_3C\text{-}\overset{O}{\overset{\Vert}{C}}OH$ (acetic acid)
Ester	$R\text{-}\overset{O}{\overset{\Vert}{C}}\text{-}O\text{-}R'$	$H_3C\text{-}\overset{O}{\overset{\Vert}{C}}\text{-}O\text{-}CH_2\text{-}CH_3$ (ethyl acetate)
Ether	R-O-R′	$H_3C\text{-}O\text{-}CH_3$ (dimethyl ether)
Ketone	$R\text{-}\overset{O}{\overset{\Vert}{C}}\text{-}R'$	$H_3C\text{-}\overset{O}{\overset{\Vert}{C}}\text{-}CH_3$ (acetone)

Note: R = any group

Practice Problems

ATOMS

4.1 Which statement is incorrect?

- a) Solutions may be homogeneous or heterogeneous. ← ALL SOLUTIONS ARE HOMOGENEOU
- b) Matter may be homogeneous or heterogeneous.
- c) Both elements and compounds are composed of atoms.
- d) All substances contain atoms.
- e) Substances are always homogeneous.

4.2 Which of the following statements is not correct?

- a) An element may be separated into atoms.
- b) An element may be a gas, a liquid, or a solid.
- c) A compound can be separated into its elements by chemical means.
- d) An element is always heterogeneous. ← IT MAY BE IF IT IS UNDERGOING A PHASE CHANGE
- e) A compound may be a gas, a liquid or a solid.

4.3 In relation to the proton, the electron is

- a) about the same mass and of opposite charge.
- b) about the same mass and of the same charge.
- c) about the same mass and with no charge.
- d) much lighter and of opposite charge.
- e) much heavier and with no charge.

4.4 A negative ion of a certain element can be formed by

- a) subtraction of a proton from an atom of that element.
- b) subtraction of an electron from an atom of that element.
- c) subtraction of a neutron from an atom of that element.
- d) addition of an electron to an atom of that element.
- e) addition of a neutron to an atom of that element.

IONIZATION POTENTIAL – ENERGY TO REMOVE AN ELECTRON FROM AN ATOM

4.5 Metallic conduction involves

- a) migration of cations toward a positively charged electrode.
- b) migration of cations toward a negatively charged electrode.
- c) migration of anions toward a positively charged electrode.
- d) passage of electrons from one atom of a metal to another.
- e) migration of anions toward a negatively charged electrode.

SIMILAR SCALE TO ELECTRONEGATIVITY (except noble gases are very large)

4.6 Which of the following statements is true?

- a) Within a group of elements in the periodic table, the largest atom has the highest ionization potential.
- b) Within a period of elements in the periodic table, the noble gas has the highest ionization potential.
- c) When all valence p orbitals of an atom are half filled, the ionization potential of that atom is lower than the ionization potential of an atom with only two electrons in the valence p orbitals.
- d) It is easier to form a $2+$ *ion* than a $1+$ ion.
- e) Ionization potential is the same as electronegativity.

1 H 13.6																	2 He 24.6
3 Li 5.4	4 Be 9.3											5 B 8.3	6 C 11.3	7 N 14.5	8 O 13.6	9 F 17.4	10 Ne 21.6
11 Na 5.1	12 Mg 7.6											13 Al 6.0	14 Si 8.2	15 P 11.0	16 S 10.4	17 Cl 13.0	18 Ar 15.8
19 K 4.3	20 Ca 6.1	21 Sc 6.5	22 Ti 6.8	23 V 6.7	24 Cr 6.8	25 Mn 7.4	26 Fe 7.9	27 Co 7.9	28 Ni 7.6	29 Cu 7.6	30 Zn 9.4	31 Ga 6.0	32 Ge 8.1	33 As 9.8	34 Se 9.8	35 Br 11.8	36 Kr 14.0
37 Rb 4.2	38 Sr 5.7	39 Y 6.4	40 Zr 6.8	41 Nb 6.9	42 Mo 7.1	43 Tc 7.3	44 Ru 7.4	45 Rh 7.5	46 Pd 8.3	47 Ag 7.6	48 Cd 9.0	49 In 5.8	50 Sn 7.3	51 Sb 8.6	52 Te 9.0	53 I 10.5	54 Xe 12.1
55 Cs 3.9	56 Ba 5.2	*	72 Hf 7	73 Ta 7.9	74 W 8.0	75 Re 7.9	76 Os 8.7	77 Ir 9	78 Pt 9.0	79 Au 9.2	80 Hg 10.4	81 Tl 6.1	82 Pb 7.4	83 Bi 7.3	84 Po 8.4	85 At —	86 Rn 10.7
87 Fr —	88 Ra 5.3	†	104 Ku —	105 Ha —													

*	57 La 5.6	58 Ce 6.9	59 Pr 5.8	60 Nd 6.3	61 Pm —	62 Sm 5.6	63 Eu 5.7	64 Gd 6.2	65 Tb 6.7	66 Dy 6.8	67 Ho —	68 Er —	69 Tm —	70 Yb 6.2	71 Lu 5.0
†	89 Ac 6.9	90 Th —	91 Pa —	92 U 4	93 Np —	94 Pu —	95 Am —	96 Cm —	97 Bk —	98 Cf —	99 Es —	100 Fm —	101 Md —	102 No —	103 Lr —

Fig. 2.28
First ionization potentials of the elements (in electron volts).

electrons. In every case, subsequent ionizations require increasingly large amounts of energy per electron. Furthermore, if the ionization requires breaking into a noble-gas configuration, an extra-large increase is observed. As an illustration, the successive ionization potentials for beryllium ($Z = 4$) are 9.32, 18.21, 153.85, and 217.66 eV, corresponding, respectively, to removal of the first, second, third, and fourth electrons.

2.8 Electron affinity

Also important for determining chemical properties is the tendency of an atom to pick up additional electrons. This property can be measured by the *electron affinity*, the *energy released when an electron adds to an isolated neutral atom.* When a neutral atom picks up an electron from some source, it forms a negative ion, as indicated by writing

$$X + e^- \longrightarrow X^-$$

The amount of energy released in this process is the electron affinity. Thus, the electron affinity measures the tightness of binding of an

4.7 Which one of the following elements has the largest atomic radius?

Correct answer is Sodium

XXXXXXXXXX

a) lithium b) sodium c) beryllium d) magnesium e) phosphorus

Li Na Be Mg P

4.8 In the series of elements *B*, *Al*, *Ga*, *In*,

a) metallic character increases from *B* to *In*.
b) electronegativity increases from *B* to *In*.
c) ionization energy increases from *B* to *In*.
d) nonmetallic character increases from *B* to *In*.
e) none of the above trends is correct.

Josh, The correct answer is sodium… phosphorous is not correct. My reasoning was that the largest number of electrons (phosphorous) would have the largest electron shell. The following was taken from Wikipedia: Atomic radius tends to increase as one proceeds down any group of the periodic table. This trend is intuitively satisfying: atoms with more electrons have larger radii. As one proceeds across any row of the periodic table, a more complex rationale is required: atoms contract in size within a period from left to right. This contraction results from the increasing number of protons in the nucleus. Protons make little contribution to the size of the atom, but they increase the positive charge of the nucleus, which draws the electrons into tighter orbitals--this is also known as the nuclear charge of the atom. My logic is true when you move down a column of the periodic table, but it is NOT true when moving from left to right. I was not aware of the effect of greater positive charge described above. I apologize for the mistake. Mark Holtzapple

4.9 Which of the following lists contains only nonmetals?

a) beryllium (*Be*), hydrogen (*H*), osmium (*Os*)
b) germanium (*Ge*), palladium (*Pd*), silicon (*Si*)
c) carbon (*C*), sulfur (*S*), fluorine (*F*)
d) calcium (*Ca*), chlorine (*Cl*), boron (*B*)
e) zinc (*Zn*), gallium (*Ga*), germanium (*Ge*)

4.10 In an element

a) the atomic number is equal to the number of neutrons in the atom.
b) the number of protons always equals the number of neutrons in the atom.
c) the mass number is equal to the number of electrons in the atom.
d) the atomic number is equal to the number of protons in the atom.
e) the number of electrons can never equal the number of neutrons in the atom.

4.11 What is the ground state electron configuration of aluminum (*Al*, $Z = 13$)?

a) $1s^2\ 2s^2\ 2p^5\ 3s^2\ 3p^1$
b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 4s^1$
d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
e) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3d^1$

LIKELY QUESTION

4.12 Which of the following electron configurations is *inconsistent* with Hund's rule (the principle of maximum multiplicity)? BUNCHED UP

a) $[Kr]\ 5s^2\ 4d^{10}\ 5p_x^2\ 5p_y^1\ 5p_z^0$ ← FREE
b) $[Kr]\ 5s^2\ 4d^{10}\ 5p_x^1\ 5p_y^0\ 5p_z^0$
c) $[Kr]\ 5s^2\ 4d^{10}\ 5p_x^1\ 5p_y^1\ 5p_z^1$
d) $[Kr]\ 5s^2\ 4d^{10}\ 5p_x^2\ 5p_y^1\ 5p_z^1$
e) $[Kr]\ 5s^2\ 4d^{10}\ 5p_x^1\ 5p_y^0\ 5p_z^1$

BEST TO PUT ELECTRONS IN AS MANY ORBITALS AS POSSIBLE

4.13 Which of these electron configurations is found in periodic Group VI?

a) $\cdots ns^2\ np^6$ b) $\cdots np^6$ c) $\cdots ns^6$ d) $\cdots ns^2\ np^4$ e) $\cdots ns^3\ np^{-1}$

4.14 From a consideration of electron configurations, which of the following elements would you expect to be most similar in chemical properties to strontium (Sr; $Z = 38$)?

a) Rb b) Y c) Sc d) Ba e) Ti

DIRECTLY UNDER Sr

4.15 The principal quantum number designates the

NLIKELY

a) shape of an orbital.
b) main energy level in which an electron is found.
c) sublevel of energy in which an electron is found.
d) number of electrons allowed in a main energy level.
e) orientation of the orbital in space.

4.16 In any atom what is the total number of electrons which can have a principal quantum number of 5 and a secondary quantum number (l) of zero?

NLIKELY

a) 2 b) 4 c) 5 d) 6 e) 18

4.17 For a neutral atom of an element in its ground state, 35 electrons occupy the energy levels up to and including the $n = 4$ energy level. If all electrons in the valence (outermost) p-orbitals are removed by ionization, how many electrons remain in the resulting ion?

NLIKELY

a) 18 b) 28 c) 20 d) 30 e) 35

4.18 How many electrons does a phosphorus atom have in its set of valence shell p orbitals?

a) 0 b) 1 c) 2 d) 3 e) 10

4.19 An atom of an unknown element Q has a mass number of 31 and the nucleus contains 15 protons. The element is

a) gallium Ga
b) sulfur S
c) phosphorus P
d) palladium Pd
e) Scandium Sc

4.20 An ion of an unknown element has an atomic number of 15 and contains 18 electrons. The ion is

a) P^{3-} b) Ar c) O^{2-} d) Si^{3-} e) S^{+}

MOLECULES

4.21 Consider the following statements about ionic and covalent bonds. Which statement is true?

a) In a covalent molecule, each atom is bonded to only two other atoms. ← COULD BE MORE
b) An ionic bond is an electrostatic interaction localized between two definite ions of identical electrical charge. ← NOT NECESSARY.
c) A covalent bond occurs when electrons are completely transferred from one atom to another. ← IONIC
d) When a covalent bond forms between two atoms with different electronegativities, the bond is always polar.
e) A compound never contains both ionic and covalent bonds.

4.22 Which one of the following compounds is classified as an alkane?

a) ethylene b) benzene c) propane d) acetylene e) ethanol

4.23 Which one of the following bonds is most covalent? (MOST SIMILAR ELECTRONEGATIVITIES)

a) $MgCl$ b) AlP c) $NaCl$ d) MgS e) NaP

4.24 The sum of the oxidation states of all the atoms in a neutral molecule

a) must be a small positive number.
b) must be a small negative number.
c) must be zero.
d) can be either positive or negative, but not zero.
e) can have any value, including zero.

4.25 The oxidation state of an element bonded only to itself (e.g. H_2)

a) must be a small positive number.
b) must be a small negative number.
c) can be either positive or negative, but zero.
d) can have any value, including zero.
e) must be zero.

RULE 1. e^- SHARED BETWEEN UNLIKE ATOMS ARE COUNTED WITH THE MORE ELECTRONEGATIVE

RULE 2. e^- SHARED BETWEEN LIKE ATOMS ARE SHARED EQUALLY

4.26 The oxidation state of sulfur (S) in the ion SO_3^{2-} is

a) 1+ b) 2+ c) 3+ d) 4+ e) 6−

SO_3^{2-}

$x + 3(-2) = -2$

$x = +4$

4.27 A mole

a) is a unit of measurement applicable only to molecules.
b) equals the number of atoms in one gram of carbon-12.
c) equals the number of molecules in 20 liters of air.
d) is Avogadro's number of anything.
e) equals the number of atoms in 22.4 liters of a diatomic gas.

4.28 Which statement is incorrect? 1/2 N_2

a) Avogadro's number equals the number of molecules in one mole of nitrogen molecules.
b) Avogadro's number equals the number of atoms in one mole of nitrogen atoms.
c) Avogadro's number equals the number of atoms in one mole of nitrogen molecules.
d) Avogadro's number equals 6.02×10^{23}.
e) Avogadro's number equals the number of one faraday of electricity (one faraday equals 96 500 coulombs — the charge carried by one mole of electrons).

4.29 An empty aluminum Coke can weighs 50 grams. How many moles of aluminum does one Coke can contain? (Atomic weight of Al = 27)

$50\,g \times \frac{mole}{27\,g} = 1.85$ mo

a) 1350 b) 1.85 c) 1.0×10^{25} d) 3.0×10^{25} e) 27

4.30 A 27 gram sample of oxygen difluoride, OF_2, contains how many molecules? (Atomic weights: O = 16, F = 19; Avogadro's number: 6.0×10^{23})

$MW = 16 + 2(19) = 54$

a) 3.0×10^{23}
b) 2 times 6.0×10^{23}
c) 6.0×10^{23} divided by 4
d) 3.0×10^{23} times 54
e) 12.0×10^{23}

$27\,g \times \frac{mole}{54\,g} \times \frac{6.02 \times 10^{23}}{mole} \cong 3 \times 10^{23}$

$MW = 2(23) + 1(32) + 4(16) = 142$

4.31 How many grams are there in 0.01 mole of Na_2SO_4?

$0.01\,mole \times \frac{142\,g}{mol} = 1.42\,g$

a) 7.1 g b) 14.2 g c) 9.6 g d) 1.42 g e) 0.71 g

4.32 What is the volume at standard temperature and pressure of 16 grams of gaseous sulfur dioxide, SO_2?

$MW = 32 + 2(16) = 64$

$16\,g \times \frac{mol}{64\,g} \times \frac{22.4\,L}{mol} = 5.6\,l$

a) 22.4 liters b) 11.2 liters c) 5.6 liters d) 16.8 liters e) 64 liters

4.33 What is the percentage by weight of aluminum, Al, in alumina, Al_2O_3? (Atomic weights: Al = 27, O = 16)

$MW = 2(27) + 3(16) = 102$

$\% = \frac{2(27)}{102} = \frac{54}{102} = 53\%$

a) 63 b) 37 c) 23 d) 53 e) 64

4.34 A certain compound consists only of sulfur (S) and chlorine (Cl). It contains 47.5 percent by weight of sulfur and has a molecular weight of 135. What is its molecular formula? (Atomic weights: S = 32, Cl = 35.5)

$\frac{32}{32 + 35.5} = 47.4\%$

a) SCl_2 b) SCl c) S_2Cl_2 d) S_2Cl e) S_3Cl

$\frac{32}{32 + 2(35.5)} = 0.31$

4.35 An unknown organic compound was analyzed and found to contain 34.6 percent carbon, 3.8 percent hydrogen, and 61.5 percent oxygen. Which one of the following compounds could the unknown be?

	MW	C %
a) methanol CH_3OH	$1(12) + 4(1) + 16 = 32$	$12/32 = 37.5\%$
b) oxalic acid CO_2H-CO_2H	$2(12) + 2(1) + 4(16) = 90$	$2(12)/90 = 26.7\%$
c) acetic acid CH_3-CO_2H	$2(12) + 4(1) + 2(16) = 60$	$2(12)/60 = 40.0\%$
d) malonic acid $CO_2H-CH_2-CO_2H$	$3(12) + 4(1) + 4(16) = 104$	$3(12)/104 = 34.6\% \leftarrow$
e) propionic acid $CH_3-CH_2-CO_2H$	$3(12) + 6(1) + 2(16) =$	

REACTIONS

4.36 What is the expression for the equilibrium constant for the following system?

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

a) $K = [NO]^2[Cl_2]^2/[NOCl]^2$
b) $K = 2[NO][Cl_2]/2[NOCl]$
c) $K = [NO]^2[Cl_2]/[NOCl]^2$ FORWARD RXN
d) $K = [NO]^3[Cl_2]^2/[NOCl]^2$
e) $K = [NOCl]^2/[NO]^2[Cl_2]$ REVERSE RXN

$K = \frac{PRODUCT}{REACTANTS}$

4.37 For the reaction of solid BaO with carbon dioxide according to the equation $BaO(s) + CO_2(g) \rightleftharpoons BaCO_3(s)$, the equilibrium expression may be represented as

a) $[BaCO_3]/[BaO]$
b) $1/[CO_2]$
c) $[BaO][CO_2]/[BaCO_3]$
d) $[CO_2]$
e) $[BaCO_3]/[BaO][CO_2]$

$\frac{\text{PRODUCTS}}{\text{REACTANTS}} = \frac{\cancel{[BaCO_3]}\ 1}{\cancel{[BaO]}[CO_2]}$ IGNORE SOLIDS

4.38 Assume excess oxygen reacts with methane to form 14 grams of carbon monoxide according to the equation $2CH_4 + 3O_2 \rightleftharpoons 2CO + 4H_2O$. How many moles of methane will be consumed?

CO MW = 12 + 16 = 28

$14\ g\ CO \times \frac{\text{mole CO}}{28 g\ CO} \times \frac{2 \text{ mole } CH_4 \text{ cons}}{2 \text{ mole } CO \text{ prod}} = 0.5$

a) 2.0 moles methane
b) one-third mole methane
c) 0.25 mole methane
d) 0.5 mole methane
e) 4.0 moles of methane

4.39 What coefficient is required for NO_2 in order to balance the equation?

$$2Pb(NO_3)_2 \rightarrow 2PbO + NO_2 + O_2$$

2 x 2 = 4

a) 0.5 b) 1 c) 1.5 d) 4 e) 10

4.40 What coefficient is required for H_2O in order to balance the equation?

$$Be_3N_2 + H_2O \rightarrow 3Be(OH)_2 + 2NH_3$$

2 x 3 = 6

a) 1 b) 2 c) 3 d) 6 e) 18

4.41 In the following reaction determine the change, if any, that occurs in the oxidation number of the underlined element, and whether the element is oxidized, reduced, or unchanged:

$$3Mg + \underline{N}_2 \rightarrow Mg_3\underline{N}_2$$

0 0 = 3(+2) + 2(−3)

→ gains e^- ∴ IT IS REDUCED

a) from 0 to +3; oxidized
b) from 0 to −3; oxidized
c) from +3 to +5; oxidized
d) from 0 to −3; reduced
e) from +5 to +3; reduced

4.42 According to the equation $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$,

a) production of 1 mole of H_2 requires 3 moles of HCl.
b) production of 1 mole of $AlCl_3$ requires 3 moles of HCl.
c) production of 2 moles of H_2 requires 2 moles of HCl.
d) production of 2 moles of H_2 requires 5 moles of HCl.
e) production of 4 moles of H_2 requires 2 moles of HCl.

4.43 When crystals of sodium sulfate are dissolved in water, the resulting solution feels warmer. The solubility of Na_2SO_4 could be increased by

∴ EXOTHERMIC

a) increasing the temperature.
b) increasing the pressure.
c) decreasing the temperature. (EASIER TO GIVE OFF HEAT @ LOW TEMP)
d) adding more solute to the solution.
e) stirring the solution.

4.44 Which of the following statements is false?

a) An exothermic reaction always goes faster than an endothermic reaction. ← THIS IS THERMO, NOT KINETICS
b) A catalyst provides a different route by which the reaction can occur.
c) Some reactions may never reach completion (100% products).
d) The rate of a reaction depends upon the height of the energy barrier (energy of activation).
e) The activation energy is independent of the energy of reaction.

4.45 In which one of the following reactions would an increase in the volume of the container cause an increase in the amount of products at equilibrium? (All substances are gases unless marked otherwise.)

∴ LOOKING FOR INCREASE IN GASEOUS MOLES

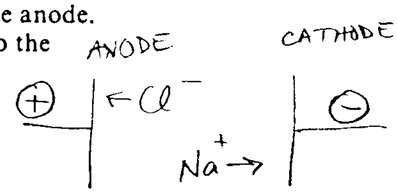
a) $2NO + 5H_2 \rightleftharpoons 2NH_3 + 2H_2O$ $5 \rightarrow 4$
b) $CH_3CHO + \text{heat} \rightleftharpoons CH_4 + CO$ $1 \rightarrow 2$
c) $SO_2 \rightleftharpoons S(s) + O_2$ $1 \rightarrow 1$
d) $SO_3 + HF \rightleftharpoons HSO_3(l)$ $2 \rightarrow 0$
e) $C + H_2O \rightleftharpoons CO + H_2$ $1 \rightarrow 2$

NORMALLY A SOLID; HERE, IT'S A GAS

98. The rates of most chemical reactions increase as the temperature increases primarily because at higher temperatures

(A) the ionic charge is higher
(B) the pressure is higher
(C) there are increases in the average distances between atoms within molecules
(D) there are more collisions involving molecules with sufficient energy for reaction
(E) the activity of the protons in the nucleus is higher

99. In electrolysis, the anions migrate to the anode. Which of the following ions migrates to the other electrode?



(A) Acidic ions
(B) Basic ions
(C) Neutral ions
(D) Zwitterions
(E) Cations

100. The statement that equal volumes of all gases under the same conditions of temperature and pressure contain very nearly the same number of molecules is known as

(A) Avogadro's law
(B) Boyle's law
(C) Dalton's law
(D) Gay-Lussac's law
(E) Graham's law

GO ON TO THE NEXT PAGE.

$2(75)+3(16)=198$ g

101. $As_2O_3 + 3\,C \rightarrow 3\,CO + 2\,As$ ← $2(75)=150$ g

Atomic weights may be taken as 75 for arsenic, 16 for oxygen, and 12 for carbon. According to the equation above, the reaction of 1 gram-mole of As_2O_3 with carbon will result in the formation of

(A) 1 gram-mole of CO
(B) 1 gram-mole of As
(C) 28 grams of CO
(D) 150 grams of As
(E) a greater amount by weight of CO than of As

102. Ethane gas burns according to the equation $2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$. What volume of CO_2, measured at standard temperature and pressure, is formed for each gram-mole of C_2H_6 burned?

$\frac{4 \text{ mole } CO_2}{2 \text{ mole } C_2H_6} \times \frac{22.4\text{ L}}{\text{mole } CO_2} = 44.8$

(A) 22.4 liters
(B) 44.8 liters
(C) 88.0 liters
(D) 89.6 liters
(E) 176 liters

103. The tendency for reaction to occur is greatest for those chemical reactions in which

(A) a large amount of heat is evolved ← DRIVEN BY?
(B) a large amount of heat is absorbed
(C) a small amount of heat is evolved
(D) a small amount of heat is absorbed
(E) no heat is absorbed or evolved

$\Delta G = \Delta H - T\Delta S$
(−) (−)
MUST BE NEGATIVE TO GO

104. The valence (oxidation state) of manganese in potassium permanganate, $KMnO_4$, is

(A) +2 (B) +3 (C) +4
(D) +5 (E) +7

K Mn O_4
$(+1)+(X)+4(-2)=0$
$X=7$

105. Element number 37, rubidium, is found in Group IA of the periodic table along with sodium and potassium. One would expect rubidium to exhibit all of the following properties EXCEPT

(A) vigorous reaction with water liberating hydrogen
(B) conduction of electric current
(C) formation of ions with a charge of +2 ← +1
(D) metallic luster
(E) vigorous reaction with halogen

GO ON TO THE NEXT PAGE.

106. Which of the following elements would NOT be expected to form a positive ion?

TOO FAR TO RIGHT ON PERIODIC TABLE

(A) Lithium (B) Sulfur (C) Magnesium
(D) Tantalum (E) Arsenic

107. $$3\,A(g) \rightleftarrows 2\,B(g) - \text{Heat}$$

ENDOTHERMIC, MOLES DECREASE

The reaction above is at equilibrium. The yield of B could be increased by

(A) decreasing the temperature but not by decreasing the pressure
(B) decreasing the pressure but not by decreasing the temperature
(C) decreasing both the temperature and pressure
(D) increasing both the temperature and pressure
(E) adding a catalyst

M

24. Astatine (At, element no. 85) is in Group VIIA of the periodic table, as are chlorine and iodine. Which of the following is not characteristic of astatine?

(A) It is a deeply colored, volatile substance.
(B) It reacts with sodium vigorously to give NaAt.
(C) It reacts with hydrogen to give H_2At. ← IT SHOULD BE HAt
(D) It is less electronegative than chlorine.
(E) It is a weaker oxidizing agent than fluorine.

25. Which of the following elements is least likely to form a negative ion?

(A) chlorine (Cl, no. 17)
(B) strontium (Sr, no. 38) IT'S A METAL ∴ MORE LIKELY TO FOR POSITIVE ION
(C) sulfur (S, no. 16)
(D) phosphorous (P, no. 15)
(E) oxygen (O, no. 8)

26. In the electrolysis of an aqueous solution of potassium bromide, what species migrates towards the positive electrode (the anode)?

(A) K^+ (B) H_2O (C) H_2O^- (D) Br^- (E) KBr

27. In order to determine the number of moles of nitrogen in 3.7 liters of the pure gas at STP, you would use

(A) the law of definite proportions.
(B) Avogadro's law.
(C) the equilibrium constant.
(D) the periodic table.
(E) Gay-Lussac's law.

28. The oxidation number (oxidation state or valence) of chlorine in potassium perchlorate, $KClO_4$, is

$$\begin{matrix} K & Cl & O_4 \end{matrix}$$
$$(+1) + x + 4(-2) = 0 \Rightarrow x = +7$$

(A) -4 (B) -1 (C) 0 (D) +3 (E) +7

29. The fact that there are fewer collisions between molecules of gases at lower temperature generally results in

(A) a smaller equilibrium constant.
(B) a smaller rate constant.
(C) Boyle's law.
(D) a larger equilibrium constant.
(E) a larger rate constant.

30. Which of the following would not increase the amount of the product in the given reaction?

$$CH_3OH + CH_3CO_2H \underset{}{\overset{HCl}{\rightleftharpoons}} CH_3CO_2CH_3 + H_2O$$

← CATALYST

(A) Addition of more CH_3OH.
(B) Addition of more CH_3CO_2H.
(C) Addition of more HCl.
(D) Removal of H_2O.
(E) Removal of $CH_3CO_2CH_3$.

M1

31. If the endothermic reaction given were at equilibrium, which of the following would shift the equilibrium to the right?

$$\text{Heat} + Br_2(g) + 2Cl^- \rightleftharpoons Cl_2(g) + 2Br^-$$

ENDOTHERMIC

GASEOUS MOLES CONST

(A) Increasing P at constant T.
(B) Decreasing P at constant T.
(C) Increasing T at constant V.
(D) Decreasing T at constant V.
(E) Letting the reaction run longer.

32. Oxidation of propene with potassium permanganate proceeds as follows (not balanced). THERE IS NO NEED TO BALANCE THIS TOTAL RXN, JUST THE CARBON

$$1\,CH_3CHCH_2 + KMnO_4 + H_2SO_4 \longrightarrow 1\,CH_3CO_2H + 1\,CO_2(g) + K_2SO_4 + MnO_2 + H_2O$$

In the balanced equation, how many liters of CO_2 would be formed from 1 mol of propene?

$$\frac{1 \text{ mole } CO_2}{1 \text{ mole propene}} \times \frac{22.4 \text{ L}}{\text{mole } CO_2} = 22.4$$

(A) 1 (B) 22.4 (C) 44.0 (D) 44.8 (E) 89.6

33. Iron reacts with copper sulfate according to the following (unbalanced) equation:

$$2\,Fe + 3\,CuSO_4 \longrightarrow Fe_2(SO_4)_3 + 3\,Cu$$

$$1 \text{ gatom Fe} \times \frac{3 \text{ gatom Cu}}{2 \text{ gatom Fe}} \times \frac{63.5 \text{ g Cu}}{\text{g atom Cu}} = 9$$

Atomic weights are Fe = 56, Cu = 63.5, S = 32, O = 16. How much copper will be formed from reaction of one gram-atom of iron with excess copper sulfate?

(A) 0.5 g-atom (B) 1.0 g-atom (C) 127 g (D) 95 g (E) 56 g

34. At the end of each of the next ten years, a payment of \$200 is due. At an interest rate of 6%, what is the present worth of the payments?

(A) \$27 (B) \$200 (C) \$1472 (D) \$2000 (E) \$2636

35. An amount P is invested at interest rate i per compounding period. F is the account balance after n compounding periods. Select the formula that relates F to P.

(A) $F = P(1 + i)^{n-1}$ (B) $F = P(1 + n)^{i}$ (C) $F = P(1 + ni)$
(D) $F = P(1 + i)^{n}$ (E) $F = P(1 + i)^{-n}$

36. \$12,000 is borrowed now at 12% interest. The first payment is \$4000 and is made 3 years from now. The balance of the debt immediately after the payment is

(A) \$4000 (B) \$8000 (C) \$12,000 (D) \$12,860 (E) \$16,860