HANDOUT SET

GENERAL CHEMISTRY II

Periodic Table of the Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.00794																	2 **He** 4.00262
2	3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.179
3	11 **Na** 22.9898	12 **Mg** 24.305											13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.97376	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.59	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.710	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
6	55 **Cs** 132.9054	56 **Ba** 137.34	57 **La*** 138.91	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0254	89 **Ac**** 227.0278	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (266)	110 (270)	111 (272)	112 ***** (277)						

*Lanthanides	58 **Ce** 140.12	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
**Actinides	90 **Th** 232.038	91 **Pa** 231.0659	92 **U** 238.0289	93 **Np** 237.0482	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Mass numbers in parenthesis are the mass numbers of the most stable isotopes. As of 1997 elements 110-112 have not been named.

***Peter Armbruster and Sigurd Hofman synthesized a single atom at the Heavy-Ion Research Center in Darmstadt, Germany in 1996. The atom survived for 280 μs after which it decayed to element 110 by loss of an α-particle

Chapter 10 and 11

Structure and Bonding

TABLE OF ELECTRONEGATIVITIES

0.5 - 0.9
1.0 - 1.4
1.5 - 1.9
2.0 - 2.4
2.5 - 2.9
3.0 - 3.5
3.6 - 3.9
4.0

H 2.1																	He --
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne --
Na 0.9	Mg 1.3											Al 1.6	Si 1.9	P 2.2	S 2.5	Cl 3.0	Ar --
K 0.8	Ca 1.3	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.6	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.7	Ga 1.6	Ge 2.0	As 2.2	Se 2.6	Br 2.8	Kr --
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 2.1	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 2.0	Sb 2.1	Te 2.1	I 2.7	Xe 2.6
Cs 0.8	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 2.0	Pb 2.3	Bi 2.0	Po 2.0	At 2.2	Rn --
Fr 0.7	Ra 0.9	Ac 1.1															

TABLE OF AVERAGE BOND ENERGIES

BOND	BOND ENERGY, kJ/mol	BOND	BOND ENERGY, kJ/mol	BOND	BOND ENERGY, kJ/mol
H—H	436	C—C	347	N—N	163
H—C	414	C=C	611	N=N	418
H—N	389	C≡C	837	N≡N	946
H—O	464	C—N	305	N—O	222
H—S	368	C=N	615	N=O	590
H—F	565	C≡N	891	O—O	142
H—Cl	431	C—O	360	O=O	498
H—Br	364	C=O	736	F—F	159
H—I	297	C—Cl	339	Cl—Cl	243
				Br—Br	193
				I—I	151

TABLE OF AVERAGE BOND LENGTHS

BOND	BOND LENGTH, pm	BOND	BOND LENGTH, pm	BOND	BOND LENGTH, pm
H—H	74.14	C—C	154	N—N	145
H—C	110	C=C	134	N=N	123
H—N	100	C≡C	120	N≡N	109.8
H—O	97	C—N	147	N—O	136
H—S	132	C=N	128	N=O	120
H—F	91.7	C≡N	116	O—O	145
H—Cl	127.4	C—O	143	O=O	121
H—Br	141.4	C=O	120	F—F	143
H—I	160.9	C—Cl	178	Cl—Cl	199
				Br—Br	228
				I—I	266

Writing Lewis Structures

1. Count valence electrons for all atoms.
   add 1 e^- for every negative charge if a polyatomic ion
   subtract 1 e^- for every positive charge if an ion

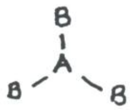
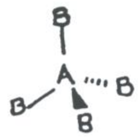
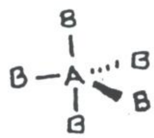
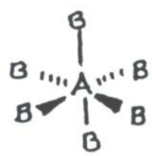
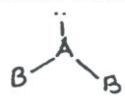
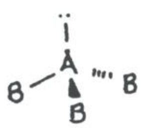
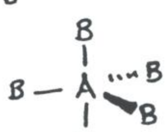
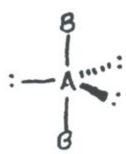
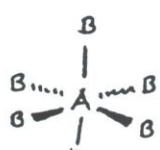
2. Draw a skeletal structure (be reasonable, some rules apply)
   H is always a terminal atom
   Certain atoms do not normally complete the octet, namely;
      H, He, Li, Be, and B (Boron completes the octet with a formal charge of +1)
   In polyatomic ions the least electronegative atom is the central atom
   H 1 bond only
   B 3 bonds normally
   C 4 bonds
   N 3 bonds (uncharged species) 4 bonds (charged species)
   O 2 bonds (normally) 1 or 3 bonds if non-zero formal charges are present
   F 1 bond normally. The other halogens are 1 bond when terminal.
   When in doubt, try <u>something</u>.

3. Place a pair of electrons between every pair of atoms which are bonded.
   Subtract the number of electrons used for bonding from the total number of valence electrons available.

4. Complete the octet on the remaining atoms with lone-pairs.
   Remember, certain atoms do not fill their octet

5. If the octets cannot be filled on all appropriate atoms, make multiple bonds.
   Structures that exhibit resonance are usually stable
   Certain atoms can expand their octet as necessary, namely the period 3 and greater elements.

GEOMETRY/SHAPE REVIEW
VSEPR THEORY

Scheme	Bonding Picture	Geometry*	Shape‡
Compounds without lone pairs on central atom			
AB_2	B− A− B	Linear	Linear
AB_3		Trigonal Planar	Trigonal Planar
AB_4		Tetrahedral	Tetrahedral
AB_5		Trigonal bipyramidal	Trigonal bipyramidal
AB_6		Octahedral	Octahedral
Compounds with lone pairs on central atom			
$:AB_2$		Trigonal planar	Bent
$:\ddot{A}B_2$		Tetrahedral	Bent
$:AB_3$		Tetrahedral	Trigonal pyramidal
$:AB_4$		Trigonal bipyramidal	Distorted tetrahedral
$:\ddot{\underset{..}{A}}B_2$		Trigonal bipyramidal	Linear
$:AB_5$		Octahedral	Square pyramidal
$:\ddot{A}B_4$		Octahedral	Square planar

*Geometry refers to the *electronic* geometry
‡Shape refers to the *molecular* shape or *molecular* geometry

VALENCE BOND THEORY AND HYBRIDIZATION

Hybridization: Mixing of non-equivalent atomic orbitals (AO's) to generate a new set of degenerate hybrid orbitals.

1. Does not occur on isolated atoms – only atoms used in bonding. Does not occur on terminal atoms.
2. Hybridization occurs to the extent that the electronic geometry predicted by VSEPR is produced.
3. Orbitals being hybridized must be in the same principle quantum shell.
4. Number of hybrids produced is equal to number of AO's used.
5. Requires energy: stabilization obtained by bond energy and repulsion stabilization.
6. Covalent bonds form as normal – *i.e.*, orbital overlap to share a pair of electrons.

Lewis Symbolism, Molecular Structure (VSEPR), and Hybridization (VB Theory)

1. Draw the Lewis structures for the following molecules or ions:

CH_2Cl_2 NH_4^+ HCN

CO_3^{2-} C_2H_4 CH_3CO_2H

2. Draw the Lewis structure of benzene, C_6H_6. Benzene is a 6-carbon ring molecule. Show also the conventionally used abbreviated drawing of benzene.

3. Draw the Lewis structure of parahydroxybenzoic acid, (PABA, $C_7H_6O_3$). PABA is an excellent UV-radiation absorber once used in sunscreens. As the name implies, PABA contains the benzene ring and the carboxylic acid group. The prefix “para” means “across the ring”.

5. Two kinds of covalent bonds exist; nonpolar covalent and polar covalent. Describe the carbon-hydrogen bond in CH_4 as either polar or nonpolar.

6. Draw the Lewis structures of the following molecules or ions. For each, indicate the electronic geometry, molecular geometry, hybridization (if any) of central atoms, and whether the molecule or ion possesses a permanent dipole moment.

	PO_4^{3-}	SeO_2	N_2H_4
electronic geometry	________________	________________	________________
molecular geometry	________________	________________	________________
hybridization	________________	________________	________________
Dipole Moment	________________	________________	________________

	XeF_4	CBr_4	C_2H_2
electronic geometry	________________	________________	________________
molecular geometry	________________	________________	________________
hybridization	________________	________________	________________
Dipole Moment	________________	________________	________________

	NO_2^-	SeO_4^{2-}	N_2F_2
electronic geometry	______________	______________	______________
molecular geometry	______________	______________	______________
hybridization	______________	______________	______________
Dipole Moment	______________	______________	______________

	SO_3	CF_2Cl_2	C_2H_4
electronic geometry	______________	______________	______________
molecular geometry	______________	______________	______________
hybridization	______________	______________	______________
Dipole Moment	______________	______________	______________

	NO	PBr_5	SF_6
electronic geometry	______________	______________	______________
molecular geometry	______________	______________	______________
hybridization	______________	______________	______________
Dipole Moment	______________	______________	______________

7. Shown below is the molecule caffeine. Describe the hybridization of every atom that uses hybridized atomic orbitals for bonding. Determine the approximate bond angles. Also indicate the type of bonds formed between atoms (*i.e.*, $\sigma(sp^2\text{-}p)$, $\pi(p\text{-}p)$, etc.) Notice that lone-pairs are omitted but assumed present; this convention is typical of many drawings of organic molecules.