Chemistry 221 Final exam
Department of Chemistry, Oregon State University

Name...EXAM KEY....

15 July 2010

$$F(formal\ charge) = number\ valence\ electrons - (bonds\ from\ atom + nonbonded\ electrons)$$

$$\frac{1}{\lambda} = Z^2R\left(\frac{1}{n_a^2} - \frac{1}{n_b^2}\right) \qquad R = 1.0 \times 10^5 cm^{-1} \qquad n_a < n_b$$

Molecular shapes predicted by VSEPR theory

Note that one electron *pair* in the present context may denote a double or triple bond.

Number of electron pairs (domains)	electronic geometry	Number of unshared pairs	molecular geometry
2	linear	0	linear
3	triangular planar	0	triangular planar
		1	bent
4	tetrahedral	0	tetrahedral
		1	triangular pyramid
		2	bent
5	triangular bipyramidal	0	triangular bipyramidal
		1	see-saw
		2	T-shaped
		3	linear
6	octahedral	0	octahedral
		1	square pyramidal
		2	square planar

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne c20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar c39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57- 71 ↓	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 210.0	85 At 210.0	86 Rn 222.0
87 Fr 223.0	88 Ra 226.0	89-103 ⇓	104 Db	105 Jl	106 Rf	107 Bh	108 Hn	109 Mt									

→	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 144.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	6 8 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
⇒	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 239.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 252.1	99 Es 252.1	1 00 Fm 257.1	101 Md 256.1	102 No 259.1	103 Lr 260.1

1. (16 pts) Provide the mass number, the atomic number and the electronic configuration of the following atoms or ions

(a) $^{14}_{7}N$ $1s^2 2s^2 2p^3$

(b) $^{28}_{14}Si$ $[Ne] 3s^2 3p^2$

(c) $^{55}_{26}Fe^{3+}$ $[Ar] 3d^5$

(d) $^{89}_{39}Y$ $[Kr] 5s^2 4d$

2. (13 pts) Periodicity. Consider the elements: K, Cs, V, Co, Br

(a) Arrange the elements from highest to lowest covalent radius.

Cs > K > V > Co > Br

(b) Arrange the elements from highest to lowest first ionization energy.

Br > Co > V > K > Cs

(c) Attach the names: metal, semi-metal, transition metal, halogen, noble (or inert) gas, alkali metal, alkaline earth to the selected elements.

K alkali metal

Cs alkali metal

V transitem metal

Co transition metal

Br halogen

29

3. (16 pts) Define these terms:

(a) diamagnetic

no unpaired electrons

(b) sigma bond

places e^- density in a chemical bond along the line connecting the atoms

(c) antibonding molecular orbital

an MO which places little e^- density between the atoms + hence destabilizes the chemical bond

(d) electron negativity

measure of the tendency of an element to hold onto its e^-

4. (8 pts) What is the frequency of the photon that photo-ionizes the last remaining electron from the 1s orbital of U^{91+}? In what portion of the electromagnetic spectrum does one find this wavelength. $h = 6.6 \times 10^{-34}$ J · s, $c = 3 \times 10^8$ m/s.

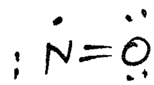
$$\nu = \frac{c}{\lambda} = c \cdot R \cdot Z^2 \left\{ \frac{1}{1^2} - \frac{1}{\infty^2} \right\} = cRZ^2$$

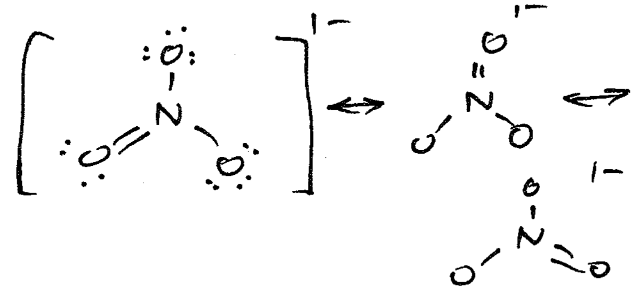
$$\nu = 10^5 \frac{1}{\text{cm}} \cdot 3\times10^{10} \frac{\text{cm}}{\text{sec}} \cdot (92)^2 = 2.5 \times 10^{19} \text{ Hz}$$

yikes! an x-ray or γ-ray.

/24

5. (12 pts) Draw the Lewis structures of NO, and NO_3^-. Include resonance structures if appropriate.





3 resonance structures

6. (9 pts) Complete the table using VSEPR and hybridization theory,

molecule	number of electron domains	molecular geometry	hybridization
AlH_4^-	4	tetrahedral	sp^3
ICl_4^-	6	square planar	d^2sp^3
XeF_4	6	square planar	d^2sp^3

/21

7. (16 pts) Suppose that the second row diatomics have molecular orbitals whose energies increase as

$$\sigma_{2s} < \sigma^*_{2s} < \sigma_{2p} < \pi_{2px}, \pi_{2py} < \pi^*_{2px}, \pi^*_{2py} < \sigma^*_{2p}$$

For the following molecules,

	N_2	O_2^-	NO^-	F_2^{2-}	C_2^{2-}
b	3	1.5	2	0	3

arrange in order corresponding to

(a) increasing bond order (smallest to largest)

$F_2^{2-} < O_2^- < NO^- < N_2, C_2^{2-}$

(b) increasing bond length

$N_2, C_2^{2-} < NO^- < O_2^- < F_2^{2-}$ (no bond probably)

(c) diamagnetic to paramagnetic

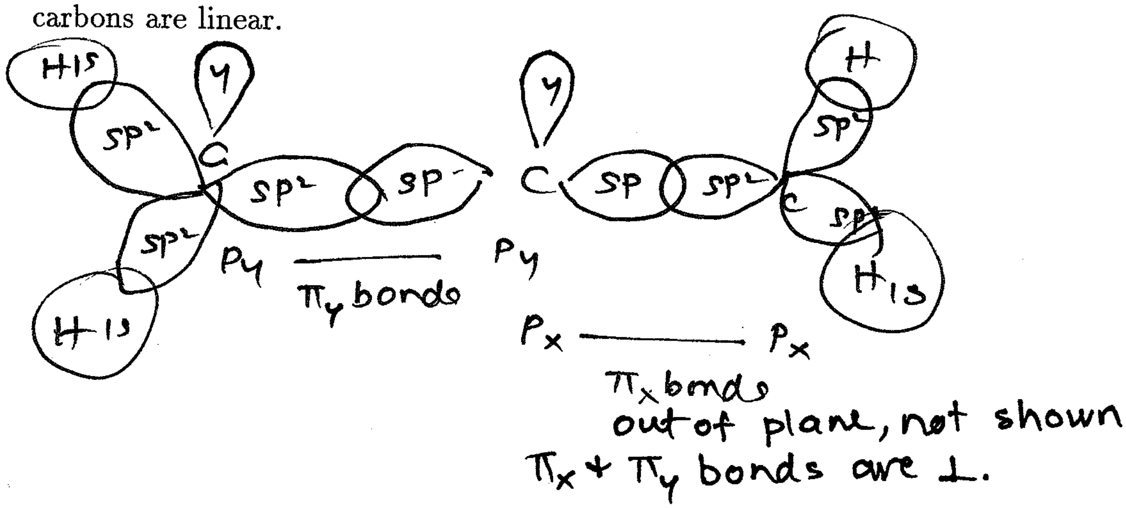
F_2^{2-}, N_2, C_2^{2-} < ~~N~~O_2^- < NO^-

(d) increasing number of anti-bonding electrons

$N_2, C_2^{2-} < NO^- < O_2^- < F_2^{2-}$

16/16

8. (10 pts) Describe the hybridization of the carbon atoms in allene, $H_2C = C = CH_2$, and make a rough sketch of the molecule using its hybrid orbitals. Note: the three carbons are linear.



9. (16 pts) Ethane is oxidized according to

$$C_2H_6(g) + \underset{7/2}{O_2}(g) \rightarrow 2CO_2(g) + 3H_2O(g)$$

(a) **Balance** the chemical equation above.

(b) Two moles of ethane (the C_2 compound) are burned in an excess of oxygen. How many moles of CO_2 are formed?

(c) For the same starting materials as in part (b), how many grams of water form?

(d) If the oxidization is performed using 96 g of molecular oxygen, then how many grams of water form?

(b) $2 \text{ moles Et} \times \frac{2 \text{ moles } CO_2}{1 \text{ mol Et}} = 4 \text{ moles } CO_2$

(c) $2 \text{ moles Et} \times \frac{3 \text{ moles } H_2O}{1 \text{ mol Et}} \times \frac{18 \text{ g } H_2O}{1 \text{ Mol } H_2O} = 6 \times 18 \text{ g} = 108 \text{ g } H_2O$

(d) $96 \text{ g} \Rightarrow 3$ moles of O_2 ∴ now the limiting reagent

$3 \text{ moles } O_2 \times \frac{3 \text{ moles } H_2O}{(7/2) \text{ moles } O_2} \times \frac{18 \text{ g } H_2O}{\text{Mol } H_2O} = \left(\frac{18}{7}\right) 18 \text{ g}$

$= 46.3 \text{ g } H_2O$

/26

10. (10 pts) Citric acid ($M_w = 192$ g) is a tri-protic acid (three titratable protons), which reacts with sodium hydroxide to form tri-sodium citrate

$$H_3Cit + 3NaOH \rightarrow 3H_2O + Na_3Cit$$

Balance this reaction. How many mL of 0.10 M NaOH would be used in a titration of 50 mL of 0.30 M citric acid (this is the acid concentration in lemons).

$$50\,mL \times \frac{1\,L}{1000\,mL} \times \frac{0.30\,M\ acid}{L} \times \frac{3\ moles\ NaOH}{1\ mole\ acid} \times \frac{1\,L}{0.10\,M\ NaOH} \times \frac{1000\,mL}{L}$$

$$= \left(\frac{50}{1000}\right) \times 0.30 \times 3 \times \frac{1}{0.10} \times 1000 = 50 \times 3 \times 0.3/0.1$$

$$= 450\,mL$$

11. (12 pts) Complete, balance and write a net ionic equation for the following reactions,

$$2\,KI(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$$

$$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$$

$$2\,HCl(aq) + Zn(s) \rightarrow H_2(g) + ZnCl_2(aq)$$

$$2H^+(aq) + Zn(s) \rightarrow H_2(g) + Zn^{2+}(aq)$$

$$2\,CsOH(aq) + H_2SO_4(aq) \rightarrow \cdots\ 2H_2O + Cs_2SO_4$$

$$2H^+ + 2OH^- \rightarrow 2H_2O$$

/22

12. (12 pts) Oxidation reduction.

(a) Determine the oxidation numbers ~~for~~ phosphorus and iron in the compound $Fe_3(PO_4)_2$.

Fe (2+)
P (5+)

(b) Write the reaction below as two reactions: an oxidation and a reduction. In those two reactions, indicate the oxidation states of the reactant and products.

$$Mn(s) + Pb(NO_3)_2(aq) \rightarrow Mn(NO_3)_2(aq) + Pb(s)$$

$Mn(s) \rightarrow Mn^{2+}(aq) + 2e^-$ oxid

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ reduction

(c) Based on the activity series what is the outcome of the following reactions, if any:

$$Mg(s) + FeCl_2(aq) \rightarrow MgCl_2 + Fe$$
$$Pb(NO_3)_2(aq) + Zn(s) \rightarrow Zn(NO_3)_2 + Pb \quad (1)$$

.... Activity series ....

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^- \quad \text{easiest to oxidize}$$
$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$
$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$
$$Pb(s) \rightarrow Pb^{2+}(aq) + 2e^- \quad (2)$$

12