Chemistry 221 Final exam 2
Department of Chemistry, Oregon State University

Name....EXAM KEY....

16 July 2009

$$\Delta H_{rx} \simeq \sum_{bonds\ broken} D_i - \sum_{bonds\ formed} D_i$$

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

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. (16 pts) Provide the electronic configuration of the following atoms or ions

(a) B $1S^2 2S^2 2p$

(b) Al $[Ne]3S^2 3p$

4 pts ea.

(c) Fe^{2+} $[Ar]4S\,3d^5$ or $[Ar]3d^6$ or $[Ar]4S^2 3d^4$

(d) La^+ $[Xe]6S^2$

2. (13 pts) Periodicity. Consider the elements: Ca, Cr, Cs, Cu, Br

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

Cs > Ca [illegible] > Cr > Cu > Br

4 pts

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

Br > Cu > Cr > Ca > Cs

4 pts

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

Cs - alkali metal

Ca - alkaline earth

Cr - transition metal

Cu - transrtron metal

Br - halogen

1 ea

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3. (12 pts) When a photon of energy 4.0 ev strikes molecular nitrogen, an electron is ejected from an orbital whose binding energy is 3.70 ev (1 ev = 1.6×10^{-19} J).

(a) What is the kinetic energy (in J) of the outgoing electron?

(b) What is the wavelength (in nm) of the incident photon?

a) $h\nu = h\nu_0 + KE, \quad KE = h\nu - h\nu_0$

$KE = 4.0\,eV - 3.70\,eV = 0.30\,eV \times 1.6 \times 10^{-19} \frac{J}{eV} = 0.48 \times 10^{-19}\,J$

b) $\lambda = \frac{hc}{E} = \frac{(6 \times 10^{-34}\,J \cdot s)(3 \times 10^{8}\,m/s)}{4\,eV \times 1.6 \times 10^{-19}\,J} = 2.81 \times 10^{-7}\,m = 281\,nm$

4. (8 pts) Rydberg's equation for the absorption and emission wavelengths of an element with nuclear charge Z and with one electron, is

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

What is the energy (in J) of the photon that photo-ionizes an electron from the 2*s* orbital of He^+?

$\Delta E = h\nu = hc/\lambda = h \cdot c \cdot Z^2 \cdot R \left(\frac{1}{4} - \frac{1}{\infty} \right), \quad Z = 2$

so $\Delta E = hcR = 6 \times 10^{-34}\,J \cdot s \cdot \left(3 \times 10^{10} \frac{cm}{sec}\right)\left(10^5 \frac{1}{cm}\right)$

$= 18 \times 10^{-19}\,J = 1.8 \times 10^{-18}\,J$

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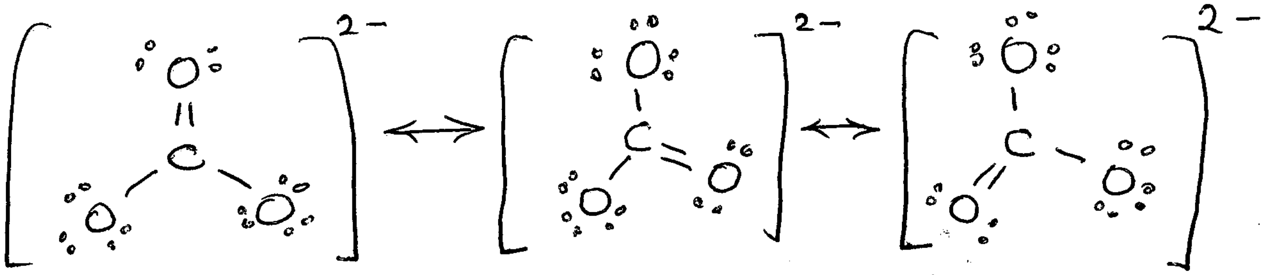
5. (16 pts) Draw the Lewis structures of CO, and CO_3^{2-}.

$:C \equiv O:$



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

molecule	number of electron domains	molecular geometry	hybridization
BF_3	3	trigonal planar	sp^2
H_2O	4	bent	sp3
SF_4	5	see-saw	dsp^3

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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,

bo	3	1.5	3	1	2
	N_2	O_2^-	NO^+	F_2	C_2
#e	10	13	10	14	8

arrange in order corresponding to

4 pts (a) increasing bond order (smallest to largest)

$F_2 < O_2^- < C_2 < N_2, NO^+$

4 pts (b) increasing bond length

$N_2, NO^+ < C_2 < O_2^- < F_2$

4 pts (c) diamagnetic to paramagnetic

$F_2, N_2, NO^+ < O_2^- < C_2$

4 pts (d) increasing number of anti-bonding electrons

$N_2, NO^+, C_2 < O_2^- < F_2$

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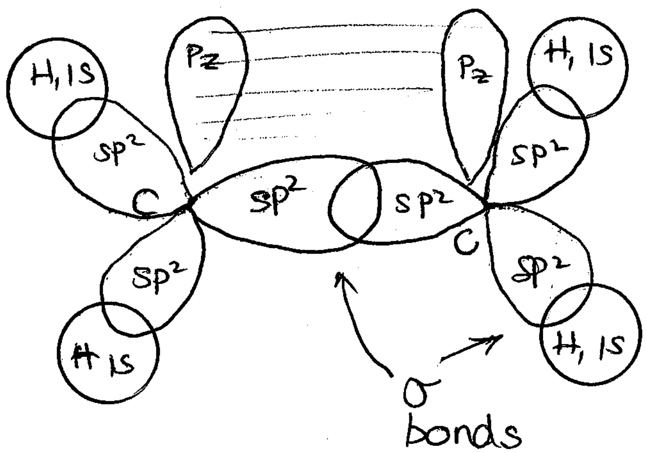
8. (8 pts) Draw the VB representation of the bonding orbitals of ethylene $H_2C = CH_2$. Include σ and π bonds.



The H, C, C, H atoms lie in plane. The P_z orbitals project above & below the plane, and form π bonds

9. (18 pts) Butane is oxidized according to

$$2C_4H_{10}(\ell) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

(a) When 2.5 moles of butane are burned in an excess of oxygen, how many moles of CO_2 are formed?

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

(c) Suppose that the oxidization is performed using 256 g of molecular oxygen, how many grams of water form?

a) $2.5 \text{ mol butane} \times \frac{8 \text{ mol } CO_2}{2 \text{ mol but}} = 10 \text{ moles } CO_2$

b) $2.5 \text{ mol but} \times \frac{10 \text{ moles } H_2O}{2 \text{ moles but}} \times \frac{18 \text{ g } H_2O}{1 \text{ mole } H_2O} = 12.5 \times 18 \text{g} = 225 \text{g } H_2O$

c) $256 \text{g } O_2 \times \frac{1 \text{ mole } O_2}{32 \text{g}} \times \frac{10 \text{ mole } H_2O}{13 \text{ mol } O_2} \times \frac{18 \text{g } H_2O}{1 \text{ mol } H_2O} = 110.8 \text{g } H_2O$

∴ O_2 is the limiting reagent.

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10. (8 pts) Salicylic acid ($M_w = 138$ g) is poorly soluble in water with a solubility of 0.2 g/100mL. How many mL of 0.10 M NaOH would be used in a titration of 50 mL of a salicylic acid, prepared at its solubility limit.

$$\frac{0.2\ g}{100\ ml} \times 50\ ml \times \frac{1\ mol\ acid}{138\ g\ acid} \times \frac{1\ mol\ base}{1\ mol\ acid} \times \frac{1000\ ml}{0.1\ mol\ base} = 7.2\ ml\ base$$

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

2 pts 2 pts

(a)

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

$$Mn(s) + Pb^{2+}(aq) \rightarrow Mn^{2+}(aq) + Pb(s)$$

(b)

$$2\,HCl(aq) + Na_2S(aq) \rightarrow H_2S(g) + 2\,NaCl(aq)$$

$$2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$$

(c)

$$Al(OH)_3(aq) + 3HNO_3(aq) \rightarrow Al^{3+}(aq) + 3NO_3^-(aq) + 3H_2O$$

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

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12. (14 pts) Oxidation reduction (2 pts ea)

(a) Determine the oxidation number for the S in SO_2; Sn in $SnCl_3^-$.

SO_2, S(+4). $SnCl_3^-$, Sn (+2)

(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.

consider just the species that change ox #'s

$$PbS(s) + 4H_2O_2(aq) \rightarrow PbSO_4(s) + 4H_2O(\ell)$$

$S^{2-} \rightarrow S^{+6} + 8e^-$ oxidized

$e^- + O^{-1} \rightarrow O^{-2}$ reduced

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

$Mn(s) + NiCl_2(aq) \rightarrow Mn^{2+}(aq) + Ni(s) + 2Cl^-(aq)$

$Cr(s) + NiSO_4(aq) \rightarrow Cr^{2+}(aq) + Ni(s) + SO_4^{2-}(aq)$

$Pt(s) + HBr(aq) \rightarrow$ no rxn

.... Activity series ....

$Li(s) \rightarrow Li^+(aq) + e^-$ easiest to oxidize

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

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

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

$H_2(g) \rightarrow 2H^+(aq) + 2e^-$

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

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