Chemistry 210 • FINAL Exam • Fall 2005 Name: Key - Vera A/C Section:_____

FREE RESPONSE: *Answer the following questions in the spaces provided. Show all work and units to receive credit. Pay attention to significant figures.*

1. (25 points) Write ***complete, balanced equations*** for the following chemical reactions (including state symbols). If you expect ***no reaction***, write ***NR*** and provide a ***brief explanation***.

   A. Aqueous solutions of sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) are mixed.

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(l)} + Na_2SO_{4(aq)}$$

   B. Write the ***molecular equation*** and ***net ionic equation*** for the reaction of $Pb(NO_3)_{2(aq)}$ with $Na_3PO_{4(aq)}$.

   MOLECULAR:

$$3\,Pb(NO_3)_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Pb_3(PO_4)_{2(s)} + 6NaNO_{3(aq)}$$

   NET IONIC:

$$3\,Pb^{2+}_{(aq)} + 2\,PO_4^{3-}{}_{(aq)} \rightarrow Pb_3(PO_4)_{2(s)}$$

   C. Chlorine gas is bubbled through a solution of aluminum fluoride.

$$Cl_{2(g)} + AlF_{3(aq)} \rightarrow NR$$ (F is more reactive than Cl)

2. (15 points) Balance the following REDOX reaction in ***acidic solution***. All species are aqueous unless otherwise indicated.

$MnO_{2(s)} + ClO^- \rightarrow Cl_2 + MnO_4^-$

$$(2H_2O + MnO_2 \rightarrow MnO_4^- + 4H^+ + 3e^-) \times 2$$

$$(2e^- + 4H^+ + 2ClO^- \rightarrow Cl_2 + 2H_2O) \times 3$$

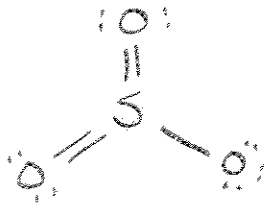
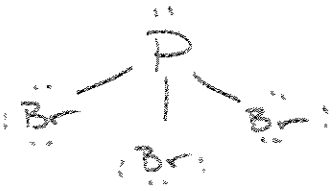
$$4H_2O + 2MnO_2 + 8H^+ + 6ClO^- \rightarrow 2MnO_4^- + 3Cl_2 + 4H_2O + 8H^+$$

$$2MnO_{2(s)} + 4H^+ + 6ClO^- \rightarrow 2MnO_4^- + 3Cl_2 + 2H_2O$$

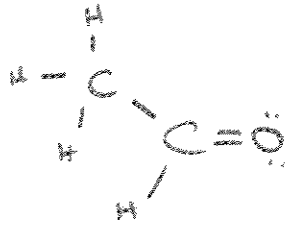
3. (8 points) Write the equation for the reaction with a heat of reaction equal to the heat of formation for $Al(NO_2)_{3(s)}$. *Include state symbols.*

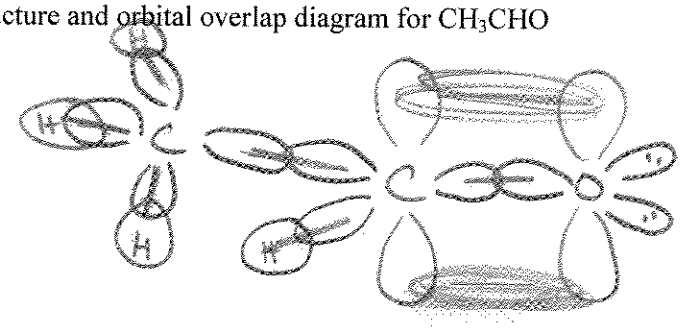
$$Al_{(s)} + \frac{3}{2} N_{2(g)} + 3O_{2(g)} \rightarrow Al(NO_3)_{3(s)}$$

4. (15 points) Draw the electron dot structure for the following molecules – assume a single central atom. Indicate (circle) whether each ***molecule*** is polar or non-polar.

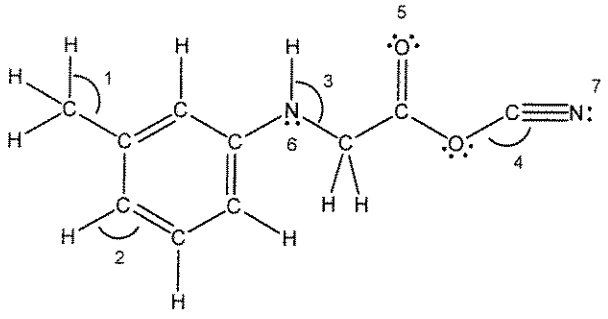
SO_3	PBr_3	NF_3
		
POLAR or NON-POLAR	POLAR or NON-POLAR	POLAR or NON-POLAR

5. (8 points) Draw the electron dot structure and orbital overlap diagram for CH_3CHO





6. (21 points) Consider the structure below:



Give the approximate bond angles of the four angles:

∠1 = 109.5 ∠2 = 120

∠3 = 107 ∠4 = 180

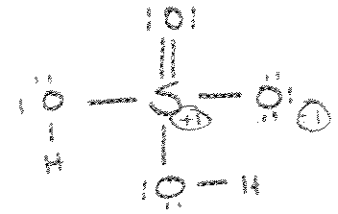
Give the hybridizations of the following labeled atoms:

#5 - O = sp^2 #6 - N = sp^3

#7 - N = sp

How many π (pi) bonds are in the structure? 6

7. (8 points) Draw the electron dot structure for sulfuric acid, H_2SO_4. Be sure to consider formal charge in drawing a reasonable structure. (A single structure will suffice.)



* Must have one S=O DB
* May have two S=O DB

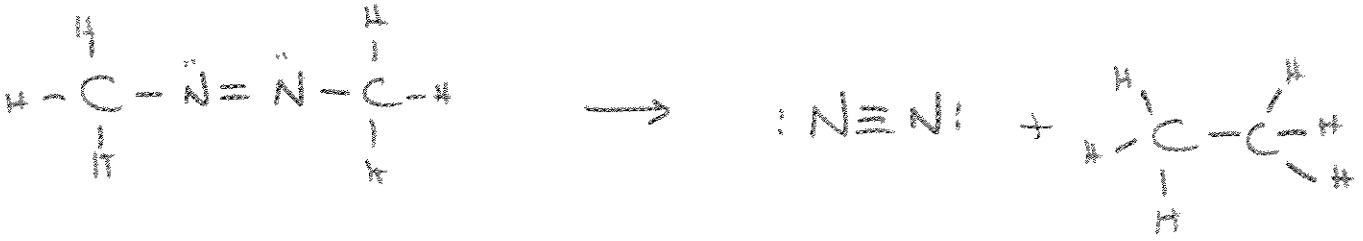
8. (6 points) Draw the electron dot structure for ***ALL*** of the reasonable resonance structures of the nitrite ion: NO_2^-

(4 points) What is the N-O bond order? $\frac{3}{2} = 1.5$

9. (15 points) When heated, azomethane decomposes into nitrogen gas and methane gas. Using bond dissociation energies, calculate the enthalpy of reaction.

$CH_3NNCH_{3(g)}$ → **$N_{2(g)}$** + **$C_2H_{6(g)}$**

(***note:*** the nitrogens are double bonded in this compound.)



~~6 C-H~~
1 N=N 418
2 C-N 305

1 N≡N 945
1 C-C 346
~~6 C-H~~

$\Delta H = [(418) + 2(305)] - [(945) + (346)] = \boxed{-263\ kJ}$

10. (15 points) Calculate the concentration (in mol/L) of aluminum ions and sulfate ions in a solution prepared by mixing 8.00 g of $Al_2(SO_4)_3$ with enough water to make 250.0 mL of solution.

342.28 g/mol

$$8.00\text{ g} \left| \frac{1\text{ mol}}{342.28} \right. = 0.02338\text{ mol}$$

$$[Al_2(SO_4)_3] = \frac{0.02338\text{ mol}}{0.250\text{ L}} = 0.0935\text{ M}$$

$[Al^{3+}] = 0.187\text{ M}$

$[SO_4^{2-}] = 0.281\text{ M}$

11. (30 points) Consider the reaction: $\mathbf{Fe_2O_{3(s)} + 3\,CO_{(g)} \rightarrow 2\,Fe_{(s)} + 3\,CO_{2(g)}}$

Molar masses (g/mol):
$Fe_2O_3 = 159.7$ CO = 28.01 Fe = 55.85 $CO_2 = 44.01$

A) What is the theoretical yield of iron if 16.0 g of iron (III) oxide is reacted with 7.25 g of carbon monoxide?

B) What mass of the excess reagent remains if a complete reaction occurs?

$$16.0\text{ g } Fe_2O_3 \left| \frac{1\text{ mol } Fe_2O_3}{159.7\text{ g}} \right| \frac{2\text{ mol Fe}}{1\text{ mol } Fe_2O_3} \left| \frac{55.85\text{ g Fe}}{1\text{ mol Fe}} \right. = 11.2\text{ g Fe}$$

$$7.25\text{ g CO} \left| \frac{1\text{ mol CO}}{28.01\text{ g CO}} \right| \frac{2\text{ mol Fe}}{3\text{ mol CO}} \left| \frac{55.85\text{ g Fe}}{1\text{ mol Fe}} \right. = 9.64\text{ g Fe} = \text{TY}$$

$$7.25\text{ g CO} \left| \frac{1\text{ mol CO}}{28.01\text{ g CO}} \right| \frac{1\text{ mol } Fe_2O_3}{3\text{ mol CO}} \left| \frac{159.7\text{ g } Fe_2O_3}{1\text{ mol } Fe_2O_3} \right. = 13.8\text{ g } Fe_2O_3 \text{ reacts}$$

$$16.0 - 13.8 = 2.2\text{ g } Fe_2O_3 \text{ remains}$$

(25 points) Answer 1 of the following 2 questions (12-13).
Cross out the one you DO NOT want graded. Otherwise the first will be graded.

12. Naturally occurring gallium is composed of two isotopes, Gallium-69 and Gallium-71. Calculate the percent abundance of the two isotopes of gallium. You MUST show all work to receive credit.

Isotope	Isotope mass
^{69}Ga	68.917
^{71}Ga	70.922

x
$1-x$

59.80% Ga-69
40.20% Ga-71

$$69.723 = 68.917x + 70.922(1-x)$$
$$69.723 = 68.917x + 70.922 - 70.922x$$
$$-1.199 = -2.005x$$
$$x = 0.5980$$
$$1-x = 0.4020$$

13. A compound is analyzed and found to contain 65.4% C, 5.5% H, and 29.1% O by mass. In a separate experiment, the compound is found to effuse through an opening at a rate of 3.0×10^{-5} mol/min. A sample of neon gas effused through the same opening at a rate of 7.0×10^{-5} mol/min.

A) What is the empirical formula of the compound?

B) What is the molecular formula of the compound?

Assume 100g of compound

$\frac{65.4\text{ g C}}{} \left| \frac{1\text{ mol}}{12.0\text{ g}} \right. = 5.45\text{ mol} / 1.82 = (3)$

$\frac{5.5\text{ g H}}{} \left| \frac{1\text{ mol}}{1.0\text{ g}} \right. = 5.5\text{ mol} / 1.82 = (3)$

$\frac{29.1\text{ g O}}{} \left| \frac{1\text{ mol}}{16.0\text{ g}} \right. = 1.82\text{ mol} / 1.82 = (1)$

emp formula = C_3H_3O

emp mass = 55 g/mol

$\frac{110}{55} = 2$

$$\sqrt{\frac{M_{m(unk)}}{M_{m(Ne)}}} = \frac{\text{rate(Ne)}}{\text{rate(unk)}}$$

Molec. formula = C_6H_6O

$$M_{m(unk)} = \left(\frac{7.0 \times 10^{-5}}{3.0 \times 10^{-5}}\right)^2 (20.2) = 110\text{ g/mol} = \text{molecular mass}$$

(30 points) Answer 1 of the following 2 questions (14-15).
Cross out the one you DO NOT want graded. Otherwise the first one will be graded.

14. Consider the reaction:

$$2\ N_2H_{4(l)} + 3\ O_{2\ (g)} \rightarrow 2\ N_2O_{(g)} + 4\ H_2O_{(l)}$$

A) Use standard enthalpies of formation to find the standard enthalpy ($\Delta H°$) for the above reaction.

B) What of mass of N_2H_4 must react to produce 500. kJ of heat?

Species	ΔH_f° (kJ/mol)
$N_2H_{4(l)}$	50.63
$N_2O_{(g)}$	82.05
$H_2O_{(l)}$	–241.83

$\Delta H°_{rxn} = 2(82.05) + 4(-241.83) - 2(50.63) - 3(0)$

$\Delta H°_{rxn} = -904.5\ kJ$

$$-500.\ kJ \left| \frac{2\ mol\ N_2H_4}{-904.5\ kJ} \right| \frac{32.06\ g\ N_2H_4}{1\ mol\ N_2H_4} = 35.4\ g\ N_2H_4$$

15. A 3.25 g sample of methanol, CH_3OH, is combusted in a bomb calorimeter. The temperature of the calorimeter increases by 10.6°C. If the heat capacity of the bomb is 855 J/C° and it contains 1.000 kg of water, what is the heat evolved per mole of ethanol combusted?

(The specific heat capacity of water is 4.18 J/g·C° and the molar mass of methanol is 32.04 g/mol.)

$$-q_{rxn} = q_{H_2O} + q_{calor}$$

$$-q_{rxn} = (1000\,g)(4.18\,J/g(°))(10.6(°)) + (855\,J/°)(10.6(°))$$

$$-q_{rxn} = 44308 + 9063 = 53371\,J$$

$$q_{rxn} = -53.371\,kJ$$

$$\frac{3.25\,g \mid 1\,mol}{32.04\,g} = 0.1014\,mol$$

$$\Delta H = \frac{-53.371\,kJ}{0.1014\,mol}$$

$$\boxed{\Delta H = -526\,kJ/mol}$$