#1. (10 points) Short Answer Questions

a) Name the following compounds:

$NaClO_2$ _____sodium chlorite_____

$MgSO_4 \cdot 5\ H_2O$ _____magnesium sulfate pentahydrate_____

b) The number of ions present in 250 mL of 0.00100 M $CaCl_2$ (aq) is:

4.52×10^{20} 2.50×10^{-4} 6.02×10^{23} 1.51×10^{20}

Note that the question asks for # of IONS, and each $CaCl_2$ unit produces 3 ions when dissolved!

c) Determine the oxidation state of the indicated element in the following:

N in N_2O_5 oxidation state: _____+5_____

O in Na_2O_2 oxidation state: _____–1_____

d) Complete the following table:

Chemical Symbol	Mass Number	Number of protons	Number of electrons	Number of neutrons
$^{133}_{55}Cs^+$	133	55	54	78

e) The standard heat of formation of solid silver nitrate is –124.4 kJ. Write the chemical equation for the reaction to which this value applies (include phases).

$$Ag(s) + 1/2\ N_2(g) + 3/2\ O_2(g) \rightarrow AgNO_3(s)$$

f) If the molar mass of a gas is doubled, the root-mean-squared speed of the molecules will increase by a factor of √2. TRUE **FALSE**

g) A standard laboratory solution contains 1.8% sodium bromide. This concentration expressed in mol/L is: _____0.17 mol/L_____

h) Which of the following gaseous processes would produce the *largest positive* change in internal energy for the system? $\Delta U = q + W \rightarrow$ so, need +q and +W

EXOTHERMIC CONTRACTION ENDOTHERMIC CONTRACTION

EXOTHERMIC EXPANSION ENDOTHERMIC EXPANSION

#2. (10 points) A sulfide of iron, containing 36.5% S by mass, is heated in $O_2(g)$, and the products are sulfur dioxide and an oxide of iron containing 30.0% O by mass.

NOTE: THIS IS ADAPTED FROM CH 4 SUGGESTED PROBLEM #98

a) What is the empirical formula of the sulfide of iron?

Let us assume 100 g of Fe_XS_Y:

$$?\ \text{mol S} = 36.5\ \text{g S} \times \frac{\text{mol S}}{32.066\ \text{g S}} = 1.14\ \text{mol S}$$

$$?\ \text{mol Fe} = (100.0 - 36.5)\ \text{g Fe} \times \frac{\text{mol Fe}}{55.85\ \text{g Fe}} = 1.14\ \text{mol Fe}$$

$$\therefore \text{Fe}_{\frac{1.14}{1.14}}\text{S}_{\frac{1.14}{1.14}} \Rightarrow \text{FeS}$$

Answer: _____FeS_____

b) What is the empirical formula of the oxide of iron?

Let us assume 100 g of Fe_XO_Y:

$$?\ \text{mol O} = 30.0\ \text{g O} \times \frac{\text{mol O}}{15.999\ \text{g O}} = 1.88\ \text{mol O}$$

$$?\ \text{mol Fe} = (100.0 - 30.0)\ \text{g Fe} \times \frac{\text{mol Fe}}{55.85\ \text{g Fe}} = 1.25\ \text{mol Fe}$$

$$\therefore \text{Fe}_{\frac{1.25}{1.25}}\text{S}_{\frac{1.88}{1.25}} \Rightarrow \text{Fe}_{1.0}\text{O}_{1.5} \Rightarrow \text{Fe}_2\text{O}_3$$

Answer: _____Fe_2O_3_____

c) Using these formulas, write a possible balanced chemical equation for the reaction described above.

oxidation states: +2 -2 0 +4 -2 +3 -2

2 FeS + 7/2 O_2 → 2 SO_2 + Fe_2O_3

oxidizing agent = O_2

d) Label the oxidation states of each element in your equation above and indicate which species is the oxidizing agent.

#3. (10 points). In the Marion lab, you mix 56.0 g of CaO with exactly 100 mL of water at 25.0°C and you observe the following reaction, as well as the release of some steam:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$

a) What is the reagent in excess and how many grams of it will be left at the end of the reaction?

NOTE: THIS IS A LIMITING REAGENT PROBLEM ALMOST IDENTICAL TO A PROBLEM I SOLVED IN DGD#5 AND ALSO VERY SIMILAR TO CH 4 SUGGESTED PROBLEM #69

$$?\ \text{mol Ca(OH)}_2 \text{ from CaO} = 56.0\ \text{g CaO} \times \frac{\text{mol CaO}}{56.077\ \text{g CaO}} \times \frac{1\ \text{mol Ca(OH)}_2}{1\ \text{mol CaO}} = 0.999\ \text{mol}$$

$$?\ \text{mol Ca(OH)}_2 \text{ from } H_2O = 100\ \text{mL } H_2O \times \frac{1\ \text{g } H_2O}{1\ \text{mL } H_2O} \times \frac{\text{mol } H_2O}{18.02\ \text{g } H_2O} \times \frac{1\ \text{mol Ca(OH)}_2}{1\ \text{mol } H_2O} = 5.55\ \text{mol}$$

∴ H_2O is the reagent in excess!

$$?\ \text{g } H_2O \text{ reacted} = 0.999\ \text{mol Ca(OH)}_2 \times \frac{1\ \text{mol } H_2O}{1\ \text{mol Ca(OH)}_2} \times \frac{18.02\ \text{g } H_2O}{\text{mol } H_2O} = 18.0\text{g}$$

$$\therefore ?\ \text{g } H_2O \text{ leftover} = 100.0\ \text{g} - 18.0\ \text{g} = 82.0\ \text{g}$$

Reagent in excess: H_2O **Mass: 82.0 g**

b) Using the data in the table below and on page 9, calculate the mass of the steam that escaped during the reaction.

CaO	**ΔH_f^o = - 635 kJ/mol**
H_2O	**ΔH_f^o = - 286 kJ/mol**
$Ca(OH)_2$	**ΔH_f^o = - 987 kJ/mol**

NOTE: THIS IS A SIMPLIFED VERSION OF PRACTICE PROBLEM B ON PAGE 283 OF PETRUCCI 10th ED.

$$\Delta H^o_{rxn} = \left[\Delta H^o_f\ \text{Ca(OH)}_2\right] - \left[\Delta H^o_f\ \text{CaO} + \Delta H^o_f\ H_2O\right]$$

$$= \left[-987\right] - \left[(-635) + (-286)\right] \text{kJ/mol} = -66\ \text{kJ/mol}$$

$$q_{rxn} = \frac{-66\ \text{kJ}}{\text{mol Ca(OH)}_2} \times 0.999\ \text{mol Ca(OH)}_2 \approx -66\ \text{kJ}$$

So, the reaction releases about 66 kJ of heat. This heat is therefore absorbed by the excess water, or:

$$\therefore q_{H_2O} = +66\ \text{kJ}$$

The 66 kJ absorbed by the 82.0 g of water must be used to do two processes: 1) to raise the temperature of the water from 25°C to 100°C and 2) to evaporate the water at 100°C to make the observed steam. Let's calculate how much heat it takes to do step 1:

$$\therefore q_{H_2O} = ms\Delta T = (82.0\ \text{g})(4.184\ \text{J/g°C})(100°\text{C} - 25°\text{C}) = +25\ 700\ \text{J} = +25.7\ \text{kJ}$$

Therefore, the "leftover" heat energy is 66 kJ – 25.7 kJ = 40.3 kJ. This is the amount of heat used to evaporate the water (step 2). We can thus calculate the mass of evaporated water (steam) using the enthalpy of vaporization (ΔH^o_{vap}) from page 9:

$$?\ \text{g } H_2O = 40.3\ \text{kJ} \times \frac{\text{mol } H_2O}{40.7\ \text{kJ}} \times \frac{18.02\ \text{g } H_2O}{\text{mol } H_2O} = 17.8\ \text{g}$$

Answer: 17.8 g

#4. (10 points) When Dr. Fox goes scuba diving, she uses NITROX, a special blend of enriched air that allows for more repetitive dives by reducing the build-up of nitrogen in the blood (that way, she won't get "the bends"!). The local scuba shop prepares 5.00 L tanks of NITROX by mixing 26.0 g of O_2 with 44.2 g of N_2 at a temperature of 25.0°C.

NOTE: THIS QUESTION WAS INSPIRED BY ASSIGNMENT #3 ITEM 2

a) What is the mole fraction of each gas in the mixture?

$$? \text{ mol } O_2 = 26.0 \text{ g } O_2 \times \frac{\text{mol } O_2}{31.998 \text{ g } O_2} = 0.812 \text{ mol } O_2$$

$$? \text{ mol } N_2 = 44.2 \text{ g } N_2 \times \frac{\text{mol } N_2}{28.014 \text{ g } N_2} = 1.578 \text{ mol } N_2$$

$$\text{Total mol } n_T = 0.812 + 1.578 = 2.39 \text{ mol}$$

$$\therefore \chi_{N_2} = \frac{1.578 \text{ mol}}{2.39 \text{ mol}} = 0.660$$

$$\therefore \chi_{O_2} = \frac{0.812 \text{ mol}}{2.39 \text{ mol}} = 0.340$$

χ of N_2 = 0.660 **χ of O_2 = 0.340**

b) What is the partial pressure of each gas, in atm?

$$P_T = \frac{n_T RT}{V} = \frac{(2.39 \text{ mol})(0.08206 \text{ L}\cdot\text{atm/mol}\cdot\text{K})(298\text{K})}{5.00 \text{ L}}$$

$$= 11.7 \text{ atm}$$

$$P_{N_2} = \chi_{N_2} \times P_T = (0.660)(11.7 \text{ atm})$$

$$= 7.7 \text{ atm}$$

$$P_{O_2} = \chi_{O_2} \times P_T = (0.340)(11.7 \text{ atm})$$

$$= 4.0 \text{ atm}$$

P of N_2 = 7.7 atm **P of O_2 = 4.0 atm**

c) What will be the total pressure left in the tank after Dr. Fox breathes 80% of it by volume during a dive?

If 80% has been consumed, there is 20% left.

V_2 is 20% of V_1 → Therefore, P_2 is 20% of P_1

P_2 = (0.20)(11.7 atm) = 2.3 atm

P_T = 2.3 atm

#5. (10 points) Steel is an alloy of iron and carbon, with iron being the major component. A steel ball has a radius of 5.85 mm and a density of 7.75 g/cm^3. If the ball contains 0.25% carbon by mass, how many ^{13}C atoms are present in the ball? The percent natural abundance of carbon-13 is 1.108%. *Recall: volume of a sphere = $(4\pi r^3)/3$*

NOTE: THIS IS VERY SIMILAR TO THE EXAMPLE PROBLEM AT THE END OF THE CHAPTER 2 NOTES, AND ALSO SIMILAR TO A PROBLEM I SOLVED IN THE DGD

This can be done in a single step using dimensional analysis. However, for clarity, I will show this solution stepwise:

$$\text{? radius of ball, in cm} = 5.85\ \text{mm} \times \frac{1\ \text{cm}}{10\ \text{mm}} = 0.585\ \text{cm}$$

$$\text{? volume of ball, in cm}^3 = \frac{4}{3} \times \pi \times (0.585\ \text{cm})^3 = 0.839\ \text{cm}^3$$

$$\text{? mass of ball, in g} = 0.839\ \text{cm}^3 \times \frac{7.75\ \text{g steel}}{\text{cm}^3} = 6.50\ \text{g steel}$$

$$\text{? mass of C, in g} = 6.50\ \text{g steel} \times \frac{0.25\ \text{g C}}{100\ \text{g steel}} = 0.0162\ \text{g C}$$

$$\text{? mol of C} = 0.0162\ \text{g C} \times \frac{\text{mol C}}{12.011\ \text{g C}} = 0.00135\ \text{mol C}$$

$$\text{? mol } ^{13}\text{C} = 0.00135\ \text{mol C} \times \frac{1.108\ \text{mol } ^{13}\text{C}}{100\ \text{mol C}} = 1.50\text{x}10^{-5}\ \text{mol } ^{13}\text{C}$$

$$\text{? atoms } ^{13}\text{C} = 1.50\text{x}10^{-5}\ \text{mol } ^{13}\text{C} \times \frac{6.022\text{x}10^{23}\ \text{atoms } ^{13}\text{C}}{\text{mol } ^{13}\text{C}} = 9.03\text{x}10^{18}\ \text{atoms}$$

Answer: _____9.03 x 10^{18} atoms_____