Name
Section
Rec TA

Side 1 of 3

Ch 1a, Problem Set One
Due Friday, Sep. 29, 2006
at 4 PM in the Drop Box

Course Policy on Significant Figures:

Numbers with decimal points should have an obvious number of significant figures. Numbers without a decimal point will have as many significant figures as there are digits through the ones place. For example, 1970 kg and 16 oz have four and two significant figures, respectively. To refer to a number with fewer significant figures, one must employ scientific notation.

For this problem set, assume that numbers reported as percentages are known to be infinitely precise. Points will be deducted for answers with the incorrect number of significant figures or the wrong units.

PART ONE – STOCHIOMETRY

1. (20 Points) During the Apollo missions, each lunar module decelerated toward the surface of the moon by the oxidation of "Aerozine-50" fuel. Aerozine-50 is a blend of hydrazine, N_2H_4, and dimethylhydrazine, $(CH_3)_2N_2H_2$, 50% by mass in each component (known to infinite precision). Nitrogen tetroxide, N_2O_4, was used as the oxidizing agent.

   Assume that 2701 kg of Aerozine-50 was used in each deceleration, and that each component underwent ideal combustion according to the following unbalanced reactions:

   $$N_2H_4 + N_2O_4 \rightarrow N_2 + H_2O \quad (1)$$
   $$(CH_3)_2N_2H_2 + N_2O_4 \rightarrow N_2 + H_2O + CO_2 \quad (2)$$

   a. (5 Pts) Write the balanced forms of these two chemical reactions.
   b. (10 Pts) Calculate the mass, in kg, of N_2O_4 used and CO_2 formed during the landing.
   c. (5 Pts) Determine the depth in centimeters of the equivalent water ice layer (density = 0.92 g/cm^3) deposited on the surface if spread evenly over a circle 1.0 km in diameter.

2. (20 Points) While browsing around the lab one day, you find a white solid in a dusty bottle with a faded label. Upon closer inspection, you find that the label says "$C_xH_yO_z$", from which you gather that the chemical contains carbon, hydrogen, and oxygen. The fragrant odor of the compound piques your curiosity, and you decide to figure out its chemical formula. You make the following observations (use 9.807 m s^{-2} for the acceleration due to gravity):

   Dissolving 0.123 g of the solid into an ethanolic solution of 250 total mL at 25.0 °C yields a solution with a density of 0.844 g/cm^3. On the osmotic pressure setup shown on p.177 of OGN, this same solution has a height, *h*, of 89.01 cm. Upon ideal combustion, 151.3 g of the white compound forms 356.2 g of CO_2 and 97.3 g of H_2O according to the unbalanced reaction:

   $$C_xH_yO_z + O_2(g) \rightarrow CO_2(g) + H_2O(g) \quad (3)$$

   a. (8 Pts) Calculate the molecular weight of the white solid.
   b. (3 Pts) Balance equation (3) for the general case of $C_xH_yO_z$
   c. (9 Pts) Determine the chemical formula of this compound.

3. (10 Points) Italian folklore suggests that adding salt to water decreases the time to bring the water to a boil. Recalling your reading from OGN (section 6.5) you test the assertion that dissolved solutes raise the boiling point of a solvent. Cooking 16 oz. of pasta might call for about 10g salt in 9 liters of water.

   a. If the water is originally at room temperature and at sea level by how much can you expect the boiling point of this saltwater mixture to change in °C?
   b. Is the temperature change in part a. appreciable for the kitchen chemist?

4. (20 Points) After eating all of the pasta from the previous test you now have a case of indigestion. This condition is caused by over-excretion of hydrochloric acid in the stomach.

   You can figure out how to neutralize the acid and cure your pains. The antacid in your medicine cabinet contains calcium carbonate, $CaCO_3$, which ultimately forms carbon dioxide, water, and a salt when it reacts with HCl. The healthy stomach pH range is 1.4 - 3.5 but yours has dropped to pH = 1.3.

   a. (4 Pts) Write a balanced equation for the complete neutralization of stomach acid (HCl) by $CaCO_3$.
   b. (8 Pts) What is the maximum number of tablets you can take safely? Each of your generic tablets is 850 mg and contains 90% $CaCO_3$ by mass. The 975 mL volume of your stomach is completely full of acid and water. You are too weak to split tablets so report your answer as an integer.
   c. (8 Pts) You were forced to round off your answer to the previous part. What would have happened in your stomach if you had taken one more tablet? What pH would you calculate for this number of tablets? Is this acceptable? (Hint: Use the simplifying assumptions that the steps in the neutralization process proceed consecutively and completely where possible.)

PART TWO – GAS LAWS

5. (10 Points) Before heading out on a road trip to Santa Barbara, you check your tire pressure. The gauge pressure of your tires, which is the difference between the pressure inside the tires and the outside pressure, is 32 psi. This morning the temperature is 58°F, and the weather report showed a pressure system of 990 millibars over the Southland (see p. 98, OGN, for pressure units). By the time you reach Santa Barbara, your tires will have warmed from excessive speeding on the 101 Freeway.

   Assuming no air leaks and that the tires have a constant volume, what is the gauge pressure in psi if the air temperature inside the tires has reached 165°F?

6. (20 Points) Nitrogen gas is slightly soluble in water: 0.024 g N_2 dissolves in 1.0 L H_2O at 1.0 atm total pressure. According to Henry's Law, solubility is proportional to pressure. Solubility increases when pressure is applied:

$$\frac{\text{Solubility at } P_2}{\text{Solubility at } P_1} = \frac{P_2}{P_1} \tag{4}$$

When a scuba diver remains in the higher pressures of the ocean depths, the nitrogen in the compressed air becomes increasingly soluble in the bloodstream. If this diver ascends to the surface too rapidly, the solubility of nitrogen decreases sharply and bubbles of N_2 form in the blood vessels, causing the painful and sometimes deadly condition known as the "bends."

a. (5 Pts) Decompression stages are necessary for divers who have spent a prolonged period below 33 feet of water. At a depth of 50 feet, what is the total pressure of water experienced by a diver? Assume the barometric pressure of air at sea level is 1.0 atmosphere, and sea water has a density of 1.025 g mL^{-1}.
b. (10 Pts) For a depth of 50 feet, calculate the concentration of N_2 which would be present in a diver's bloodstream. Express this concentration in parts per million by mass (ppm). Assume that blood is composed primarily of water, and that N_2 solubility is temperature independent.
c. (5 Pts) Say that a 75 kg diver has 8% total body weight in blood. If this person suddenly rises to the surface from a depth of 50 feet, what volume of N_2 gas, in mL, will be formed as a result of the decrease in solubility? Assume a normal body temperature of 98.6°F and the barometric pressure in the first part.

This is the end of Problem Set One. Remember this set is due in the Ch1 homework box near the mailboxes by Lloyd House. If you are unsure where this is located, ask an upperclassman to show you.

These sets will be collected five minutes after the due date and time. Be prompt in turning in your set! As with all sets, PS1 is due at 4PM on Friday.