Chemistry 123 | **DUE MONDAY, January 20, 2003 @ 6:30 p.m.** | **Winter Term 2003**
Assignment #2 | **2 Pages / 4 Problems** **SHOW YOUR WORK!** | **Instructor: R. Rossi**

Your Name: ____

At what time and on what day was this handed in? ______________________________

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1. Nitrogen gas is slightly soluble in water: at 37°C, 9.4 mg of N_2 will dissolve in one liter of water exposed to air at a total pressure of one atmosphere. However, this solubility increases linearly with the partial pressure of nitrogen, according to Henry's Law: $\text{Solubility}_{@P_2} = \left(P_2 / P_1\right) \text{Solubility}_{@P_1}$
This is of great concern to divers, who enter a high-pressure environment when they descend into the ocean. If they are breathing compressed air and spend a long time under water, their blood will become saturated with N_2 at elevated levels. When they return to the surface, the rapid reduction in pressure leads to a rapid reduction in the solubility of N_2. Bubbles of N_2 gas form in their blood vessels, causing the painful and dangerous condition known as the "bends." (Most deep-sea divers use more expensive mixtures of He and O_2 in their tanks, because He doesn't dissolve in water [or blood] to an appreciable extent. He is also inert, so its use avoids the "rapture of the deep" condition known to occur at elevated blood nitrogen concentrations. See p. 211 of Zumdahl and/or p. 536 of Jones/Atkins for more details.) Rob, your foolish instructor, has spent 58 minutes looking for lost treasure 77 feet below the surface of Lake Superior and has only 2 minutes of air left in his compressed air tank.
   a. Calculate the total (absolute) pressure, in Pascals, at Rob's depth of 77 feet. Assume a reasonable [not necessarily exact] value for the atmospheric pressure at the surface of Lake Superior, and for the density of the water in this cold, fresh-water lake. (Two significant figures is enough here.)
   b. Calculate the concentration of N_2 in Rob's blood, assuming he has come to equilibrium with the air in his tank at the pressure from part (a). Express this value in ppm_{mass} (parts per million by mass).
   c. If the total liquid volume of Rob's circulatory system is 4.5 ℓ, what volume of N_2 gas will form in his bloodstream if he suddenly rises to the surface and his blood returns to atmospheric pressure?

Units: 1 meter = 3.2808 feet   1.0000 atmosphere (atm) = 760.000 torr = 101325 Pascals (Pa) $1 \text{ Pa} \equiv 1 \text{ kg}\cdot\text{m}^{-1}\cdot\text{s}^{-2}$

Data: density of pure $H_2O \equiv \rho_{H_2O} = 1.00 \text{ g}\cdot\text{m}\ell^{-1}$ at 4ºC, $0.9982 \text{ g}\cdot\text{m}\ell^{-1}$ at 20ºC   acceleration of gravity $\equiv g = 9.80665 \text{ m}\cdot\text{s}^{-2}$

Hints: Rob's static, or diastolic, internal "blood pressure" is about 70 torr, but please ignore this in your calculations. Rob claims his body temperature is 37°C, but other sources claim he's cold-blooded. Assume Rob's telling the truth in this case, and that the cited solubility at 37°C can be used as a basis for both the submerged-Rob and surfaced-Rob calculations.

You may assume the density of water is a uniform $1.0 \text{ g}\cdot\text{cm}^{-3}$, as long as it remains a liquid, and that blood is effectively just water. (Though some say it's thicker than that.)

Here are two ways to calculate the total pressure at a given depth under the surface of a liquid:

1) Use the equation $P = P_o + \rho g h$, in which P is the total pressure at some depth h under a liquid of density ρ, g is the acceleration of gravity ($9.80665 \text{ m}\cdot\text{s}^{-2}$) here on earth, and P_o is the pressure at the surface of the liquid. To get into pressure units, you'll need to know that $\underline{1} \text{ Pascal} \equiv \frac{\underline{1} \text{ kg}}{\text{m}\cdot\text{s}^2}$
While this equation is not described in Zumdahl, examples of its use appear in two reserve books: on p. 180 of Jones/Atkins and p. 92 of Oxtoby & Nachtrieb. Any general physics textbook should also explain this equation.
2) Work from the definition of pressure, force per unit area. Choose an arbitrary area and calculate the force exerted by a volume of water of the appropriate height sitting on top of it. Just don't forget to add the pressure exerted by the atmosphere to get the total pressure! (In effect, this is just like $P = P_o + \rho gh$, but you understand why it works!)

2. Camphor is a naturally-occurring, covalently bonded (and thus non-dissociating) white solid with a distinct, fragrant smell. Similar to naphthalene, it sublimes appreciably at room temperature. Camphor has an unusual chemical structure, which was not immediately understood. You have been asked to determine its chemical formula. You gleefully zip off to lab and ascertain the following:
   1. When 0.0500 g of camphor is dissolved in 200. mℓ of ethanol at 25.0°C, a solution is formed having an osmotic pressure of 52.58 cm of solution. The density of the (osmosis-diluted) solution is 0.789 $g \cdot cm^{-3}$.
      (The concentrated camphor solution will raise a column of solution to a height of 52.58 cm in the apparatus shown in Figure 11.16 on page 540 of Zumdahl. In order to convert this to a pressure you will have to use one of the techniques listed in the final hint for #1, above. The density of the solvent (ethanol) is ≈ 0.789 $g \cdot cm^{-3}$.)
   2. When camphor undergoes complete combustion according to the unbalanced reaction

      $$\text{Camphor}_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

      250.0 g of purified camphor will react with O_2 to form 722 g of CO_2 and 235 g of H_2O.
      (This is determined using the method described in Figure 3.5 on page 93 of Zumdahl.)

   Given that camphor contains only carbon, hydrogen, and oxygen, use the data above to determine:
   a. The molar mass ("molecular weight") of camphor [Use the data in part (1) to do this!]
   b. The chemical formula of camphor (round off to whole numbers of atoms)
   c. The percent yields of CO_2 and H_2O in your combustion experiment, based on the rounded-off chemical formula from part (b) and the 250.0 g mass you started with.
      Hint: Make proper use of significant figures if you want to get (c) right! You can *check* your answer in a reference book.

   Hints: Solving part (a) before (b) and (c) should make your life *much* easier! Don't assume the empirical formula is the answer!

3. Last year, the Kiersaw-Barton family moved from Pueblo, NM to the town of Black Wolf, just outside of Oshkosh, WI. Their new home uses well water, which has a high iron concentration, and so they soften it with an ion-exchange type salt-based water softener. In January, the Kiersaw-Barton family flies south for a warm Disney vacation. They turn the heat off in their house completely when they leave. That seems like a smart energy-saving measure to them, and it's what they always did when they lived in New Mexico…alas! They now live in the great white north, and they are likely to learn a painful climatological lesson. With the heat completely off, the temperature in their home begins to plummet…and before long, their water pipes will get cold enough that they will be at risk of freezing. If that happens, their pipes will burst and their home may well flood. Not a pretty picture! Will freezing point depression save them from this terrible fate?!? Let's find out. The well water coming into the home is rich in minerals, as specified in the table below. The water softener is in the basement, without power, but it completely softened all the water that currently sits in the pipes in the rest of the house before the electricity was turned off.
   a. At what temperature will the unsoftened well water freeze, assuming the ions listed in the table below are the only ones warranting consideration? (That is, assume the concentration of any other impurities present in the water to be negligible.)
   b. At what temperature will the softened water inside the house freeze, given the means by which ion-exchange water softeners do their thing?

   Hint: You may ignore ion pairing effects in working out this problem, they are negligible at these low concentrations.

Principal Ions Present in (unsoftened) Water in the Town of Black Wolf	
Ion Identity	Ion Concentration (ppm by mass)
Chloride, Cl^-	216
Sodium, Na^+	56
Calcium, Ca^{2+}	78
Magnesium, Mg^{2+}	30.
Sulfate, SO_4^{2-}	40.
Iron(III), Fe^{3+}	18

4. Charlie tells me that the Titanic sank in 28ºF water. Clearly, the water was a liquid, not frozen. How is that possible? Why wasn't the water frozen? Is this consistent with the solubility of NaCl in H_2O?
   Hint: You'll need to look up the solubility of NaCl in water, either in a book or on the web. Be sure to *cite* the source of the number you use in answering this question, for example, "www.gofish.com/titanic/details.htm, accessed on January 12, 2003."