Chemistry 123 **DUE FRIDAY, January 10, 2003 @ 6:30 p.m.** **Winter 2003**
Assignment #1 **4 Pages / 4 Problems** **SHOW YOUR WORK!** **Instructor: R. Rossi**

General guidelines for working out Chem 123 problem sets:

1. **The most important function of the homework is to help you learn. You're going to make mistakes when trying something new, and homework is the place for it. Make a point of LEARNING from your mistakes now so you don't *repeat* them later, on an exam!**
2. **Please show your work and explain your logic on each problem; you will be graded more on your thought process than on the accuracy of your answers. Think of Chem 123 problems as a mix of essay question and math problem, not just one of the two.**
3. **Organize your work and make your writing legible. Assemble your pages together in the proper order. We will not grade horribly unorganized or illegible work!**
4. **Place your homework in the box outside my office in Mudd 167 if you don't hand it in during class. Staple it, with this problem statement on the outside, and write your name in the blank provided on the problem statement. There's a stapler outside my door!**
5. **While we won't be cruel about significant figures, you will loose big points if you repeatedly show reckless abandon with regard to the precision of your answers!**
6. **In some cases I give "realistic" problems, in that I don't specify exactly every number you will need, and include some numbers that are irrelevant. For example, I might not specify the room temperature in a problem that requires it, but include the temperature at the north pole for no good reason. *This is intentional, and meant to break people of the habit of piecing together all the numbers in a problem to get the right answer. In cases like these, make and state reasonable assumptions for the numbers you need ("I assume the room temperature to be 300 K"), and ignore the numbers that you don't.***

The "Early Bird Bonus" ("EBB") System

Assignments handed in up to 10 hours before their due date will not be penalized for up to 10% of the mistakes made therein. Specifically, for each hour before the due date, up to a maximum of 10 hours, 1% of the possible points will be put in that assignment's EBB allocation. Errors made in doing that assignment will be ignored up to the EBB allocation, then marked off normally.

Example: Pikachu hands in her(?) homework 3 hours early. The assignment is worth 100 points. She has a 3 point EBB. She makes 7 points worth of mistakes. Her recorded score will be 100-(7-3)=96 points. Jigglypuff hands in her(?!?) homework 10 hours early. She makes only 3 points worth of mistakes we can find. She gets 100, not 107. Stay-Puff doesn't hand in his homework. Rob threatens him with a sharp stick and a hot fire. Elmo hands in his homework days before it is due but has little clue of what he's doing. He makes 75 points worth of mistakes. His recorded score will be 100 - (75-10) = 35 points.

Rationale: Most people obsess over their homework until the second it is due, trying to make it perfect. [Don't ask me how I know...] The EBB system encourages you to relax on the small stuff and go have fun (or work on another class) once you have the big picture well in hand.

FAQ (Frequently Asked Questions):

No, you will not be able to get more than 100% on anything because of the EBB. If you hand something in 10 hours early, and it is perfect, you get 100%, not 110% on it. [Perhaps you should consider teaching this class…or at least prefecting!]

Your Name: ____

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

A Crash Course in Dimensional Analysis ***(See also §1.6 in Zumdahl)***

This is a very powerful tool to which you may never have been introduced. Dimensional analysis is a method of keeping careful track of units, which can be extremely helpful in solving problems in the sciences, especially in physics and chemistry. You won't always want to use it, because it can slow you down, but it will often prevent you from making mistakes.

Suppose I want to figure out the number of moles of CO_2 present in a cube of dry ice, 2.0 inches on a side. I'm told the density of dry ice is 1.35 $g \cdot m\ell^{-1}$, and that 12 inches = 1 ft = 30.48 cm.

I'd start by calculating the volume of the dry ice: $V = (2.0\text{ in})^3 = 8.0\text{ in}^3$

I can also figure out the molar mass of CO_2: $\tilde{m} = 12.0\text{ g/mol} + 2(16.0\text{ g/mol}) = 44.0\text{ g/mol}$

(This calculation can be carried out using dimensional analysis as well, but it's one of those cases where it slows you down without helping much.) [I used only three significant figures in the $\tilde{m}$ calculation because the 2.0 inch value has two significant figures. A molar mass value generally shouldn't limit the number of significant figures in any calculation you carry out, but there is no need to always calculate molar masses to the limits of your periodic table.]

Now I need to get from 8.0 in^3 to moles. This is where dimensional analysis can help.

Notice that the equation $12\text{ inches} = 30.48\text{ cm}$ can be rearranged to give $\dfrac{30.48\text{ cm}}{12\text{ in}} = 1$

Now by "multiplying by one," or more correctly a fraction equal to one, I can convert from cubic inches to cubic centimeters. Note the need to cube the conversion factor:

$$8.0\text{ in}^3\ CO_2 \times 1 = 8.0\text{ in}^3\ CO_2 \times 1^3 = 8.0\text{ in}^3\ CO_2 \times \left(\frac{30.48\text{ cm}}{12\text{ in}}\right)^3 = 13_{1.1}\text{ cm}^3\ CO_2$$

Multiplying by lots of fractions equal to one lets me work out the entire problem:

$$8.0\text{ in}^3\ CO_2 \times \left(\frac{30.48\text{ cm}}{12\text{ in}}\right)^3 \times \left(\frac{1\text{ m}\ell}{1\text{ cm}^3}\right) \times \left(\frac{1.35\text{ g } CO_2}{1\text{ m}\ell\ CO_2}\right) \times \left(\frac{1\text{ mol } CO_2}{44.0\text{ g } CO_2}\right) = 4.0_{22}\text{ mol } CO_2$$

Notice that if you cancel out units on the left side, you get the units of the answer on the right!

For goodness' sake, keep careful track of your units! They will allow you to determine whether or not you have done everything right, and if you haven't, what you still have to do in order to make things right! A number for which you don't know the units (or know that it is *dimensionless*) is useless in the sciences…just like saying "I have 42!" "42 what, for crying out loud?!?" Notice that I have also kept track of significant figures, but I haven't rounded off the result. Instead, I have written a couple non-significant figures in subscript at the end of the number. Please get in the habit of doing this! It avoids rounding errors without leading you to forget the limitations of the results of your calculations due to the inherent uncertainty in the numbers that go into them.

A note about this problem set:

These problems involve fundamental concepts from the list of topics you should know when entering Chem 123, http://www.acad.carleton.edu/curricular/CHEM/SelfEval/ReviewTopics.html These problems will probably be new for everyone in their more contextual nature, but the principles you will apply in order to work them out should already be familiar. If you are really stumped by this problem set, the first thing you should do is take the self-administered Chem 123 placement test, http://www.acad.carleton.edu/curricular/CHEM/SelfEval/SelfEval_Main.html *My general advice is that if you learned this stuff in the past but it's rusty, don't worry. If you didn't* ***really learn*** *this stuff in high school, even if you took a class that "covered" it, take Chem 122. This problem set and the resources above are primarily intended to help you place yourself!*

1. The Apollo 11 spacecraft was launched on a Saturn V rocket using "Aerozine 50" as fuel. Aerozine 50 is a blend of hydrazine (N_2H_4) and dimethylhydrazine [$(CH_3)_2N_2H_2$], 50.0% by mass in each component. Nitrogen tetroxide (N_2O_4) was used as the oxidizer. Assume that the two components of Aerozine 50 underwent complete combustion according to the following (unbalanced) reactions:

$$N_2H_4 + N_2O_4 \rightarrow N_2 + H_2O$$

$$(CH_3)_2N_2H_2 + N_2O_4 \rightarrow N_2 + H_2O + CO_2$$

If 1420 kg of Aerozine 50 was consumed in the ascent, please provide the following:

a. Balanced forms of the two chemical reactions shown above

b. The mass (in kilograms) of nitrogen tetroxide consumed in the ascent

c. The mass (in kilograms) of carbon dioxide formed as a result of the ascent

d. The equivalent volume of water (in liters at 4°C, 1 atm) generated in the ascent (the volume of liquid water you'd get if you condensed all the water that was formed)

Hints: Help on balancing reactions like these is provided in a cute format on the Zumdahl CD, in the Chapter 3 Exploration entitled "Conservation of Mass and Balancing Equations." The density of liquid water at 4°C and 1 atm is 1.00 $g \cdot m\ell^{-1}$.

2. Last August, Alex and I went on a road trip out west. When we left Northfield, the ambient air temperature was 76ºF and the atmospheric pressure was 29.0 inches of mercury. I checked my tire pressure and found it to be a uniform 32 psig (pounds per square inch, gauge pressure). After a few days of driving, we spent a night in Idaho at Henry's Lake State Park, which I consider to be one of the most beautiful places on earth…sigh. I awoke to an air temperature of 42°F and an atmospheric pressure of 23.7 inches of mercury.

a) Predict the reading on my tire pressure gauge, in psig, when I checked my tires at Henry's Lake. You may have to make some assumptions in order to answer this problem: clearly state any assumptions you decide to make! Lacking better information, I'd assume I didn't inflate or deflate my tires along the way!

b) As we began a serious ascent into the Bighorn Mountains, Alex and I periodically heard strange shuffling and stretching sounds coming from our food bag. Finally, there was a loud pop, which really got our attention. Worried, we went through the back seat carefully, only to discover that an unopened bag of chips we had bought in Minnesota had broken open, literally popped like an over-inflated tire. Why did this happen? Be explicit but qualitative in your explanation, not quantitative.

Hints: The air in my tires can definitely be treated as an ideal gas under these conditions, given the number of significant figures in the given information. Gauge pressure is defined as the difference between absolute pressure and atmospheric pressure, e.g., 1 psig ≈15.$_7$ psi absolute at sea level on a "normal" barometric pressure day, when the atmospheric pressure is 14.$_7$ psia (pounds per square inch, absolute). Note that the ideal gas law and its simplified forms require **absolute** units, and will generally give ludicrous results if non-absolute units are used! There is a handy table of unit conversions in the back of Zumdahl, in Appendix 6, on page A28. Values for the gas constant, R, are given on the inside back cover of Zumdahl.
Notes: B*arometric* pressure is corrected for altitude, it's not equal to the atmospheric pressure! Ambient temperature and atmospheric pressure both drop with increasing altitude, other things being equal.

3. David Horowitz, wacky host of the product-testing TV show "Fight Back!" has fallen ill following his attempt to eat just one of a certain brand of potato chip. To your shock, you have been asked to fill in for him. On today's show you're supposed to subject a new brand of drain opener, GunkOut, to a "Commercial Challenge." GunkOut is airing an ad claiming that "just one cup of our super-concentrated powder will fill a sink with the most concentrated solution of drain-clearing power anywhere!" Like most drain openers, this one uses sodium hydroxide (NaOH, a strong base) as its active ingredient. The solubility of NaOH in water is impressive: a saturated solution at room temperature is 20.378 M. The density of such a saturated solution is 1.53 $g \cdot m\ell^{-1}$, while the density of solid NaOH is 2.13 $g \cdot m\ell^{-1}$. The show's producer has clogged up a sink and filled it with 1 gallon of water. If you give the GunkOut folks the benefit of doubt and assume their product is pure NaOH, is there any chance their claim is valid, and that following their directions can produce a saturated aqueous NaOH solution in the gallon of water that inhabits the sink? Support your assertion by calculating the following:
   a. Express the solubility of NaOH in units of (g of NaOH per 100 g of H_2O)
   b. Determine the concentration of a solution formed by mixing 1 solid cup of NaOH with 1 gallon of water. Express this as (g of NaOH per 100 g of H_2O), unless you are confident you can estimate the density of the solution to get the molarity.

Hints: Remember that molarities (M) are expressed as moles per liter of SOLUTION, not per liter of solvent! That matters in this problem! Cups, quarts, and gallons are *still* common U.S. measurement units. [How embarrassing!]

Unit conversions: 4 cups = 1 quart = 1/4 gallon $1\ m^3 = 1000\ \ell = 264.17$ gallons = 1056.68 quarts

4. As described in Zumdahl on page 82, the natural isotopic distribution of Ne is 90.92$\%_{at}$ ^{20}Ne, 0.257$\%_{at}$ ^{21}Ne, and 8.82$\%_{at}$ ^{22}Ne. This means that 90.92% of the neon atoms in a natural sample are ^{20}Ne, 0.257% are ^{21}Ne, and the remaining 8.82% are ^{22}Ne.
   a. Verify that the average atomic mass for Ne given in the periodic table at the front of Zumdahl, 20.18 $g \cdot mol^{-1}$, agrees with the information above, within the implicit uncertainty in the given values.

   You unexpectedly become the proud owner of a 1.00 ℓ flask containing 1.00 mole of Ne atoms from a natural source, at 26°C. In order to properly brag about it to your friends, you decide to calculate
   b. the $\%_{mass}$ of each Ne isotope in your flask
   c. the $\%_{mole}$ of each Ne isotope in your flask
   d. the partial pressure of each Ne isotope in your flask

Hints: Be careful! This is not a difficult problem but it is very easy to oversimplify it, or make it inordinately difficult! It is also a problem in which your results can be made pretty darn worthless if you don't pay attention to significant figures.

Remember, please include these problem description pages with your work when you hand it in. Please staple the pages of your homework together. I keep a stapler outside my office door, if you don't happen to have one. If you're really stuck and you can't staple your assignment together, please DON'T do that funky fold-the-corner-and-tear thing. It just makes it harder for us to staple your assignment together for you.

Doing your homework on the back side of whole sheets of "already been used" paper is not only OK, it's dandy. But please don't use sheets that are smaller than full size, or pages with writing on the side you do your work on. Grading leads to enough headaches as it is! =)