CHEMISTRY DIMENSIONAL ANALYSIS INTRODUCTION

Dimensional Analysis is not for everyone. But it's probably for you. First of all then, who should avoid Dimensional Analysis (DA)?

Reasons For Not Using Dimensional Analysis

1. Let's say you're super-intelligent and enjoy solving relatively simple problems in the most complex manner.

2. Let's say you're tired of always getting the correct answers.

3. Let's say you're an arty type and you can't be confined by the structure of DA. You like messy solutions scribbled all over the page in every which direction. It's not that you want to make a mistake, but you really don't care that much about the answer. You just like the abstract design created by the free-wheeling solution. You also like the freedom from being confined by structure.

4. Let's say that you have no interest in going to the prom or making a school athletic team, and you don't mind being unpopular, ignorant, insecure, uninformed, and unpleasant.

Otherwise,

You **Need** Dimensional Analysis!

Testimonials:

"I was a student who dozed off while my teacher taught us dimensional analysis in chemistry. I never quite got the hang of it. It irritated me... all of those fractions. I never really liked fractions. Although my grades had been pretty high, I got a D in chemistry and subsequently dropped out of chemistry in the first quarter of my junior year. It was not long before all I did was watch TV and get into trouble.....eventually leading to a life of crime. I have recently learned dimensional analysis and realize how simply it could have solved all of my problems. Alas, it is too late. I won't get out of prison for 10 years and even then, my self image is permanently damaged. I attribute all of my problems to my unwillingness to learn dimensional analysis."

.... Alfred E. Newman

"I thought I knew everything and that sports was the only thing that mattered in high school. When our teacher taught our class dimensional analysis, I didn't care about it at all. I was making plans for the weekend with my girlfriend who loved me because I was a running back and not because of chemistry. While other kids were home solving dimensional analysis problems, I was practicing making end sweeps. Then one day I was hit hard. My knee was gone. Splat. I was despondent. My girl friend deserted me. My parents started getting on my case about grades. I decided to throw myself into my school work. But I couldn't understand anything. I would get wrong answers all of the time. I now realize that my failure in school came from never having learned dimensional analysis. Alas, I thought everyone else was smarter than me. After the constant humiliation of failing I finally gave up. I am worthless. I have no friends, no skills, no interests. I have now learned dimensional analysis, but it is too late. "

.... Barry Bungleditup

The evidence:

Studies in our high school from 1994-97 show that 100% of high school students who do not use and understand dimensional analysis are seriously insecure by their college year. Damage done from this deprivation in high school is probably permanent and cannot be overcome by learning the method later in life. We recommend mastering this skill before your graduate from high school.

85% of the students who went to the senior proms from 1994-97 admitted hat they enjoyed solving problems with Dimensional Analysis in order to impress and confuse their parents. Of the remaining 15%, 11% were home from the senior prom before 11 PM and 4 % went home alone.

Dimensional Analysis

Dimensional analysis (also known as “unit analysis”) is an extremely simple (yet useful) problem solving method. It will be a great advantage to learn it and to use it, since you will be doing various kinds of unit conversions throughout this course.

Dimensional analysis allows us to convert a number in one unit (such as meters) into another unit (such as centimeters) by using a **conversion factor.** You already know that 1 meter = 100 centimeters, but what does that equality mean?

- It means that there are 100 centimeters in 1 meter and there is 1 meter for every 100 centimeters.
- Or, we could say that there are 100 centimeters *per* meter and 1 meter *per* 100 centimeters.

The term “per” implies a fraction, so we can express our original equality as follows:

$$\frac{100\text{ cm}}{1\text{ m}} \quad \text{and} \quad \frac{1\text{ m}}{100\text{ cm}}$$

Each of these fractions expresses the same relationship. Every time you measure out a meter, you are also measuring 100 centimeters.

Which is larger, a meter or a centimeter? Does it make sense to you that there will be lots of centimeters in a meter? If not, take a look at a meter stick.

Express the following as pairs of fractions. Tell yourself in words what each of these means:

- 454 grams = 1 pound
- 1 meter = .001 kilometer
- 1 nanosecond = 10^{-9} seconds.

The fractions (conversion factors) are easily used to convert between units. Follow the example below to see how it is done:

Example 1: What is the capacity in liters of a gasoline tank that holds 18 gallons?

1. **Restate the problem and translate into an equation.** This question essentially asks “how many liters are in 18 gallons?” Thus, some number in liters *equals* 18 gallons. This can be written as:

   ? L = 18 gallons

2. **Determine an appropriate conversion factor.** In order to convert 18 gallons to liters, we must multiply by a conversion factor (or fraction, as above). We want to cancel “gallons,” so gallons should appear in the *denominator* of the fraction. Remember that multiplication by a conversion factor does not change the *value* , but only the *units* in which the value is expressed. Since 1 gallon = 4 quarts, we can write the following:

$$? \text{ L} = 18 \text{ } \cancel{\text{gallons}} \times \left(\frac{4 \text{ quarts}}{1 \text{ } \cancel{\text{gallon}}} \right)$$

3. **If the unit remaining does not match the unit desired in the answer, additional conversion factors must be used.** Remember: The unit in the denominator of each conversion factor must cancel the unit in the numerator of the previous conversion factor (and vice versa).

   In this problem, we can convert quarts to liters by using the following conversion factor:1 Liter = 1.06 quarts:

$$? \text{ L} = 18 \text{ } \cancel{\text{gallons}} \times \left(\frac{4 \text{ } \cancel{\text{quarts}}}{1 \text{ } \cancel{\text{gallon}}} \right) \times \left(\frac{1 \text{ Liter}}{1.06 \text{ } \cancel{\text{quarts}}} \right)$$

4. **Verify that all unwanted units cancel and that the desired units remain.**

   Indeed, we are left with liters, so the problem is ready to be solved.

5. **Perform the calculation(s) and check your answer.**

$$? \text{ L} = 18 \text{ } \cancel{\text{gallons}} \times \left(\frac{4 \text{ } \cancel{\text{quarts}}}{1 \text{ } \cancel{\text{gallon}}} \right) \times \left(\frac{1 \text{ Liter}}{1.06 \text{ } \cancel{\text{quarts}}} \right) = 68 \text{ Liters}$$

Performing the mathematical operation results in an answer of **68 Liters** (2 significant figures).

Example 2: **A car is traveling 65 miles per hour. How many meters will it travel in one second?**

Solution:

$$? \frac{\text{meters}}{\text{sec}} = \frac{65 \text{ } \cancel{\text{miles}}}{\cancel{\text{hour}}} \times \left(\frac{1.609 \text{ } \cancel{\text{km}}}{\cancel{\text{mile}}} \right) \times \left(\frac{1000 \text{ meters}}{\cancel{\text{km}}} \right) \times \left(\frac{1 \text{ } \cancel{\text{hour}}}{3600 \text{ sec}} \right) = \frac{\textbf{29 meters}}{\textbf{sec}}$$

Practice Problems (complete on separate paper):

1. 2.44 meters equals how many millimeters?
2. 5.00 miles equals how many feet?
3. 2.5 tons equals how many kilograms?
4. A car has a fuel efficiency rating of 38.9 miles per gallon. What is that rating in kilometers per liter?