**Solving Chemical Problems**

In this section, you will learn how to solve problems in a systematic way. This is the most valuable skill you need to acquire. The technique involved in this process is known as **dimensional analysis** (or unit analysis or factor-label method). In this method, the units are used as guide to solve chemistry problems. Units should always be associated with numbers in calculations. Just like algebraic quantities, the units are multiplied, divided, canceled if the same unit appears in the numerator as well as in the denominator. Let us illustrate the concept beyond the dimensional analysis using a simple example.

Let us say that you would like to know how many cents are there in 3.5 dollars. Of course, you know that there are 350 cents. But the question is how to solve this very simple problem systematically using the dimensional analyses? Here what you want to do is to convert the dollars (which is a unit) into cents (which is a unit). For that you need a standard conversion factor, which is

1 dollar = 100 cents

The answer you are seeking is in cents units. Thus, you would write,

cents = 3.5 dollar x (100 cents / 1 dollar) = 350 cents

desired unit derived unit

Here, the dollar unit in the numerator cancels with the dollar unit in the denominator; only the cents unit emerges in the answer that is exactly what we want. If you set up the problem correctly, the units on the both sides of the equation should be the same, i.e., desired and derived units should be the same. The role of the conversion factor is to transform the given quantity into desired quantity:

desired quantity = given quantity x conversion factor.

**Pitfalls**

Consider the following two scenarios.

**Scenario 1:**

Suppose you did the calculation without using the unit and came with answer as 350 like the following calculation.

= 3.5 x (100 / 1) = 350

Even though the answer 350 is technically correct, it has no meaning because it is not displaying what kind of quantity it is. The number 350 could be anything. Hence it is important to use the units in the calculation.

**Scenario 2:**

Suppose, you used the units and set up the problem following way,

$$\text{cents} = 3.50 \text{ dollars} \times \left( \frac{1 \text{ dollar}}{100 \text{ cents}} \right) = 0.035 \frac{\text{dollars}^2}{\text{cents}}$$

What a mess! Compare the desired and derived units and see that they do not agree at all. Besides, the derived unit looks absurd. This illustrates the improper way of using the standard conversion factor.

These two scenarios stress the importance of using the units and setting up the problem in right way.

**Things to Remember:**

- First of all, read the question very carefully and try to understand what the question asking for.
- Find the appropriate conversion factor or factors
- Set up the problem with proper units and cancel the same unit in the numerator and denominator. Careful in using the conversion factors; meaning could be devastating if you turn them upside down. **Setting up the problem in a correct manner is the most important and crucial step. If you master this step, then you will have an easy sail in problem solving.**
- Check your answer for units, sign, and significant figures if desired. The derived unit should match the desired unit; otherwise, you did not set up the problem correctly.

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**Example**

If your weight is 145 lbs, what is your weight in kg? (1 lb = 454 g, and $1\text{kg} = 1 \times 10^3$ g)

**Answer**

This problem can be solved in two different ways; (a) using multiple step procedure, (b) single step procedure.

**Multiple steps:**

Step 1: The given quantity is in lb and is converted to grams (lb ⟶ g).

$g = 145 \text{ lb} \times (454 \text{ g} / 1 \text{ lb}) = 65{,}830 \text{ g} = 6.5830 \times 10^4 \text{ g}$

Step 2: The answer from step 1 ($6.5830 \times 10^4$ g) is converted to kg (g⟶ kg).

$\text{kg} = 6.5830 \times 10^4 \text{ g} \times ( 1\text{kg} / 1 \times 10^3 \text{ g}) = 65.830 \text{ kg} = 6.5830 \times 10^1 \text{ kg}.$

Therefore, the answer is 65.830 kg.

**Single step:**

It is always desirable to solve the problem in a single step fusing the above both steps as follows.

$\text{kg} = 145 \text{ lb} \times ( 454 \text{ g} / 1\text{lb} ) \times ( 1 \text{ kg} / 1 \times 10^3 \text{g} ) = 65.830 \text{ kg} = 6.5830 \times 10^1 \text{ kg}$

**First, you learn how to set up the problem step-wise (multiple steps) until you are an expert or know what you are doing. Once, you master the technique, you move on to setting up the problem in a single step.**

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**Example**

Your height is 5 ft and 6 in. What is your height in meters? (1 ft = 12 in, 1 in = 2.54 cm, and 1 m = 100 cm)

**Answer**

First, 5 ft are converted to inches and then 6 inches is added to that as follows.

$\text{in} = 5 \text{ ft} \times ( 12 \text{ in} / 1\text{ft}) + 6 \text{ in} = 66 \text{ in}$

Now, the problem to solve for m is set up as follows.

$m = 66 \text{ in} \times (2.54 \text{ cm} / 1 \text{ in}) \times (1 \text{ m} / 100 \text{ cm}) = 1.68 \text{ m}$

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So far, you have learned how to set up and solve one-dimensional (linear) problems. But you also need to learn how to solve two- and three-dimensional problems that are illustrated in the following two examples.

**Example**

An area of a room is 250 $m^2$. What is this area in $cm^2$ and $mm^2$?

**Answer**

The conversion factors needed here are: 1 m = 100 cm and 1 cm = 10 mm.

Therefore,

$$cm^2 = 250\ m^2 \times (100\ cm / 1m)^2 = 2.5 \times 10^6\ cm^2$$

Note that the conversion factor (100 cm / 1 m) is squared in order to cancel the $m^2$ associated with 250. Next step is to convert $2.5 \times 10^6$ $cm^2$ to $mm^2$.

$$mm^2 = 2.5 \times 10^6\ cm^2 \times (10\ mm / 1\ cm)^2 = 2.5 \times 10^8\ mm^2$$

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**Example**

The volume of an object is 375 $cm^3$. What is this volume in $mm^3$? (1 cm = 10 mm)

**Answer**

$$mm^3 = 375\ cm^3 \times (10\ mm / 1\ cm)^3 = 3.75 \times 10^5\ mm^3$$

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